COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

Part A. REGIONAL STRUCTURE AND HYDROCARBON POTENTIAL (Cont.)

By Robert C. Milici, Donald C. Le Van and Gerald P. Wilkes

NATURAL GAS POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUST SHEETS

Natural gas is currently being produced from five counties in southwestern Virginia, primarily from formations of Mississippian age. In addition oil is produced from two small fields, the Rose Hill and Ben Hur fields, from Ordovician formations in the fenster region of the Pine Mountain block. The current rate of hydrocarbon production in Virginia is about 8.5 billion cubic feet of natural gas and 8,000 barrels of oil annually. Locations of fields and oil and gas tests in Southwestern Virginia are shown in Figure 2-1; wells are described in Table 1.

Mississippian strata occupy synclinal troughs along the footwall of the Pulaski fault for approximately 90 miles (145 km) from Craig County to Smyth County, Virginia. Similarly, the Greendale syncline comprises the footwall of the Saltville fault, containing Mississippian-age strata along most of its length for almost 200 miles (about 320 km) from Bland County, Virginia to Grainger County, Tennessee. Basal Mississippian and older strata were tested for natural gas by the Kipps well in the Price Mountain window, Montgomery County and by the Westinghouse well in Washington County, and produced gas in the Early Grove field in Scott County, Virginia (Figures 2-1, 2-2). In Tennessee, Devonian black shales were tested recently with some success in Grainger County by the U.S. Department of Energy and these beds, together with underlying Devonian and Silurian sandstone reservoirs, are currently being explored by industry.

Gruy Federal No. 1, Grainger County: Fractured Devonian shale reservoirs were drilled and stimulated by the U.S. Department of Energy (DOE), through its contractor Gruy Federal, Inc., in Grainger County, Tennessee in early 1980 (Figure 2-2). The well, located in the Grainger County Industrial Park, was spudded in Cambrian formations in the hanging wall of the Saltville thrust; the well entered the Grainger Formation (Mississippian) at 667 feet (203 m). The Chattanooga Shale (Devonian-Mississippian) was encountered from 1136 feet (346 m) to 1856 feet (566 m), an apparent thickness of 720 feet (219 m).

The Wildcat Valley Sandstone (Devonian) beneath the Chattanooga Shale contained some light-gravity oil, which was observed in fractures in core. The Chattanooga produced little gas initially, but upon stimulation of selected zones yielded 50 Mcf (thousand cubic feet) per day, together with 50 bbl a day of slightly acidic water. The well was given to Grainger County for operation upon completion of the tests (Dean, 1980 and personal communication).

Early Grove Gas Field: The discovery of the Early Grove gas field (1931) was based upon a report by Charles Butts (1927), who identified an anticlinial structure within the Greendale syncline and recognized its importance as a potential hydrocarbon trap (Figure 2-3). The discovery well was drilled on the highest part of the structure to a depth of 3613 feet (1101 m) and had an initial production of 1,750 Mcf per day from calcareous sandstones within the Little Valley Limestone (Mississippian) (Figure 2-3, map well No. 4, Table 2). Ten wells were drilled prior to 1958; the gas, which was produced until 1958, was delivered to the City of Bristol. A 1980 development well in the field is reported to have encountered significant amounts of natural gas and additional tests are planned.

The deepest well in the field was Tidewater-Wolfs Head, E. D. Smith No. 1. The well was drilled to 7220 feet (2200 m) and bottomed in the Sequatchie Formation (Figure 2-4). Gas was encountered in Mississippian limestones and the well was completed as a shut-in gas well. Initial open flow of gas was measured as 60 Mcf per day. Following acid treatment, gas flow increased to 223 Mcf per day before stabilizing at 84 Mcf per day after 20 hours. (Data are from files of Virginia Division of Mineral Resources; Averitt, 1941; Le Van, 1959; and Le Van, unpublished report).

Thermal maturities determined by conodont color changes (CAI-Conodont color index) indicate that hydrocarbons in the Valley and Ridge in eastern Tennessee and in Southwestern Virginia are suitable for natural gas production, but that they are too mature to yield commercially significant amounts of oil. (Harris and Milici, 1977, pl. 1).

Principal stratigraphic targets in the footwalls of the Saltville and Pulaski thrust sheets are Mississippian sandstones, Devonian black shales, Silurian sandstones and Ordovician shales and limestones. Source rocks of significance are the Ordovician shales and shaly limestones, Devonian shales and possibly some shales and shaly limestones and coal of Mississippian age.

In addition to regional geologic map patterns, Vibroseis lines in eastern Tennessee performed for the Tennessee Division of Geology under a contract to the U.S. Department of Energy show that strata as young as Mississippian may extend beneath the eastern end of the Saltville and Pulaski thrust sheets (Figure 2-2) (Milici, Harris and Statler, 1979). These rocks are only moderately folded and faulted. Cross section A-A′ in Figure 2-2, based upon interpretations of Vibroseis lines TC-1 and TC-2, shows Devonian shales acting as the footwall lubricant for the Pulaski and Saltville thrust sheets, although younger beds may persist farther eastward beneath the thrust sheets than is shown (Figure 2-5). In addition, the interpretation of the TDG-DOE Vibroseis lines by Milici, Harris and Statler (1979) as well as data presented subsequently by Harris and Bayer (1980) show that Paleozoic sedimentary strata with hydrocarbon potential extend beneath the Blue Ridge and perhaps beneath the western part of the Piedmont.

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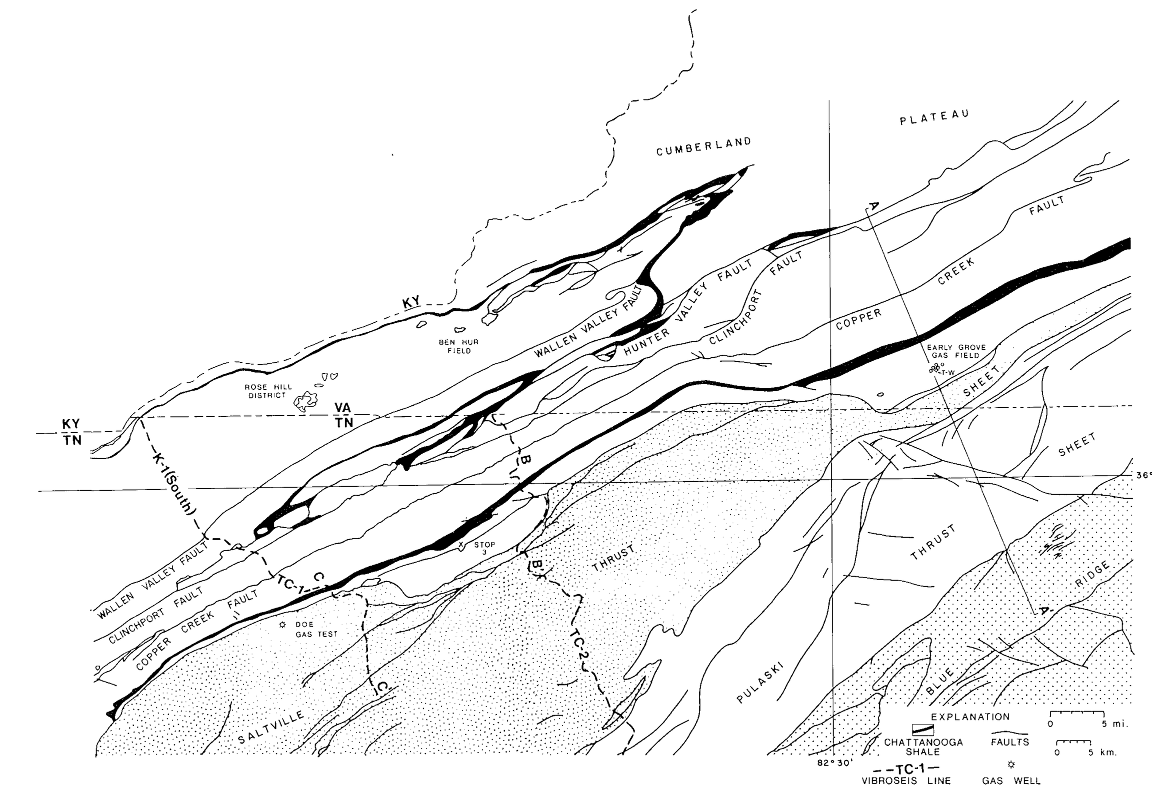

FIGURE 2-2. Tectonic map and cross sections of Southwestern Virginia and northeastern Tennessee. Symbols for cross sections follow. Rocks: P—Pennsylvanian undivided; M—Mississippian undivided; Mn—Newman Limestone; Mg—Grainger Formation; MDc—Chattanooga Shale; Du—Devonian undivided; Sc—Clinch Sandstone; SO—Silurian and Ordovician undivided; O—Ordovician undivided; Omb—Martinsburg Formation; Ols—Ordovician limestones undivided; Osv—Sevier Shale; O€: Ordovician—Cambrian O€k—Knox group; €c—Conasauga Group; €hk—Honaker Formation; €r—Rome Formation; b—basement. Faults: HVF—Hunter Valley fault; CF—Clinchport fault; CCF—Copper Creek fault; SVF—Saltville fault; PF—Pulaski fault; BRF—Blue Ridge fault. Sections have no vertical exaggeration.

TABLE 1—Significant wells drilled for oil and gas in the Valley and Ridge Province of Southwestern Virginia (compiled by D. C. Le Van). Well numbers correspond to those on Figure 2-1.

Map Well No.	*Operator*	*Property and Well No.*	*TD (ft.)*	*Remarks*
1	—	Gearhart Farm	1000′±	Dry hole, about 1929
2	The California Company	Kipps Anthracite Coal Co. No. 1	9340′ in Ordovician (Moccasin)	Dry hole, 1949 Gas shows in Ordovician (Martinsburg) W-62
3	The California Company	F. P. Strader No. 1	1443′ in Knox Group	Dry hole, 1948 W-136
4 & 5	C. L. Hottle	C. E. Richardson Nos. 1 and 2	One well 1400′± other unknown	Dry holes (drilled 20′ apart), date unknown Shows of oil and gas
6	Holly Brook Oil & Gas Co.	—	3300′	Dry hole, 1923
7	United Producing Co., Inc.	J. M. Hoge No. 1—1532	5632′ in Cambrian (?)	Dry hole, 1950 W-12
8	I. C. Groskins and others	Andrew Newberry No. 1	1295′±	Dry hole, 1950 W-152
9	Mathieson Chemical Corp.	J. L. Sanders Heirs No. 1	2985′	Dry hole, 1953
10	Mathieson Chemical Corp.	T. K. McKee No. 1	2727′	Dry hole, 1949 W-3607
11	Westinghouse Electric Corp.	Morton Salt Co. No. 1	5455′ in Devonian (Chemung)	Dry hole, 1976 W-4625
12	Gulf Oil Corp.	W. Russell Price No. 1	17,003′ (basement test)	Dry hole, 1977 Gas shows in Ordovician W-5653
13	Holston Oil and Gas Co.	W. E. Leonard No. 1	2600′±	Dry hole, about 1910
14	Holston Oil and Gas Co.	Bailey Barker No. 1	2500′±	Abandoned, gas burned rig, about 1915
15	Tidewater Oil Co. Wolfs Head Oil Refining Co.	E. D. Smith No. 1	7218′ in Ordovician (Sequatchie)	Gas well (shut in) in Mississippian (Little Valley) 1964 Gas show in Silurian (Clinch) W-951
16	Trans-State Oil Ltd.	Bruce Riggs No. 1	2140′	Dry hole, 1970 Oil show in Silurian (Clinch) W-2488
17	Castle and Jenkins	W. B. Osborne No. 1	4861′ in Ordovician	Dry hole, 1950 Gas show (personal communication) W-44
18, 19, 20	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 1	759′ (?)	Abandoned, 1961-2 W-691
	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 2	—	Abandoned; (20′ from No. 1)
	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 3	3912′	Dry hole; (near No. 1 & No. 2) W-987
21	Appalachian Oil & Mineral Development Co., Inc.	M. Robinette No. 1	1389′ (?)	Dry hole, 1962 W-640
22	C. E. Deaton	M. H. Snodgrass No. 1	1706′ in Cambrian (Copper Ridge)	Oil show in Ordovician (Chepultepec) Dry hole, 1947 W-116
23	Cedar Valley Oil Co.	D. C. McClure No. 1	3250-3400′ (?)	Gas show, in Ordovician (Trenton?) Dry hole, 1915
24	Clarence Ellison (K. R. Wilson)	Charles Phipps No. 1	1902′ in Silurian (Clinch)	Dry hole, 1947 W-107
25	R. R. Murray	Anthony Ely No. 1	2532′ in Ordovician (Hardy Creek)	Gas and oil shows; flowed gas from Ordovician (Reedsville) at about 100,000 cfgpd Abandoned, 1947 W-61
26	Lee Oil Drilling Co.	D. L. Graybeel No. 1	7209′ in Ordovician	Tested 2 BOPD from Ordovician (Moccasin) Dry hole, 1977 W-5227
27	Robert Vorhees	Mill Davis No. 1	4406′ in Ordovician (Mascot)	Oil shows in Ordovician (Trenton) Dry hole, 1947 W-75
28	H. & R. Oil Co.	Grant Smith No. 1	2188′ in Ordovician (Hardy Creek)	Oil show in Ordovician (Trenton) Dry hole, 1948 W-145
29	K. R. Wilson	E. C. H. Rosenbaum No. 1	1456′ in Silurian (Clinton)	Abandoned, 1947 W-153
30	K. R. Wilson	O. Cavins No. 1	2001′ in Ordovician (Chepultepec)	Dry hole, 1947 W-98
31	Shell Oil Co.	L. S. Bales No. 1	8020′ in Cambrian (Copper Ridge)	Dry hole, 1965 Gas shows in Ordovician and Cambrian Dead oil shows W-1273
32	Virginia Lee Oil Co. (Fitch *et al.*)	E. M. Brooks No. 1	4079′ in Ordovician (Eggleston)	Gauged 225,000 cfgpd gas, from Silurian (Hancock) gas show in Clinch, oil shows in Ordovician Abandoned, 1945 W-80.
33	Rouge Oil Co.	Henley Sutton No. 1	4000′ (OWDD)	Gas show Dry hole, 1947, 1954 W-118
34	Johnson, Head, & Gilmore	Billy Parkey No. 1	2650′	Show of "oily gas" Abandoned, 1929

Abbreviations: TD—total depth of well
W-136, Virginia Division of Mineral Resources Well Sample Number
BOPD—barrels of oil per day
cfgpd—cubic feet of gas per day
OWDD—old well drilled deeper

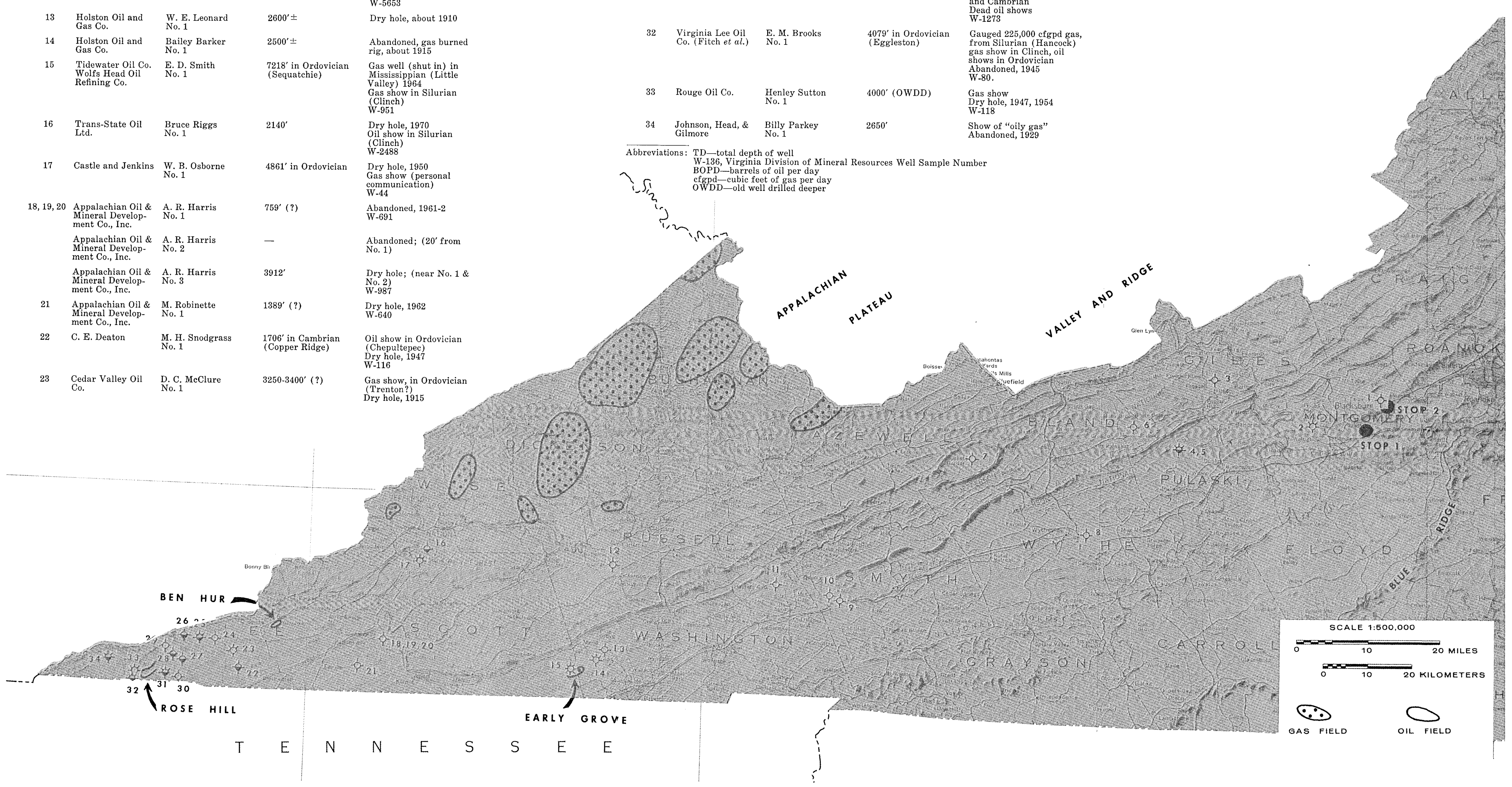

FIGURE 2-1. Location map for Southwestern Virginia, showing *Stops 1* and *2*, significant oil and gas tests, and oil and gas fields (compiled by D. C. Le Van).

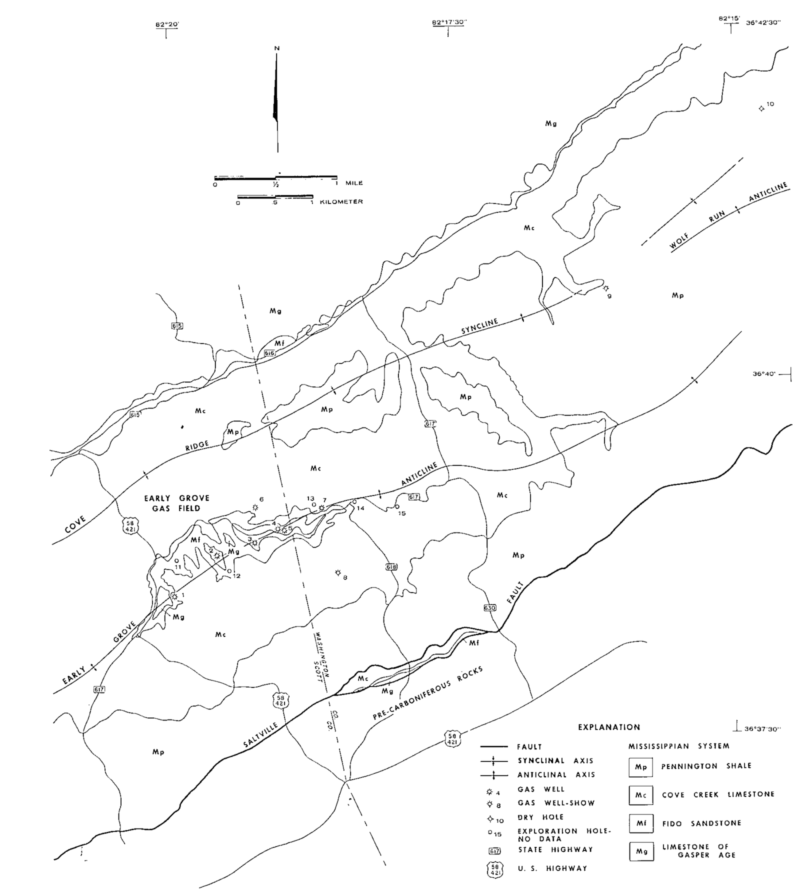

FIGURE 2-3. Geologic map and well locations in Early Grove gas field (After Averitt, 1941).

TABLE 2—Well data from the Early Grove Area, Scott and Washington counties, Virginia (compiled by G. P. Wilkes). Well numbers correspond to those on Figure 2-3.

Map Well No.	*Operator*	*Property and Well No.*	*El. (ft.)*	*TD (ft.)*	*Remarks (cfgpd)*
1	Bristol Natural Gas Co.	H. A. Miller No. 1 (8)	1562′	5862′ (OWDD)	Gas well (127,000 in Mississippian rock; 30,000 in Devonian rock)
2	Davis Elkins (Bristol Natural Gas Co.)	C. B. & J. H. Hunsucker No. 1 (3)	1507′	3721′	Gas well (abandoned) in Mississippian rock (200,000)
3	Davis Elkins (Bristol Natural Gas Co.)	E. S. Ridgeway No. 1	1461′	3613′	Gas well in Mississippian rock (1,750,000)
4	Tidewater-Wolf's Head	E. D. Smith No. 1	1456′	7218′	Shut in gas well (gas show in Mississippian rock)
5	Bristol Natural Gas Co.	E. D. Smith No. 5	1459′	3435′	Gas well in Mississippian rock (1,500,000)
6	Davis Elkins (Bristol Natural Gas Co.)	G. W. Fleenor No. 4	1511′	3854′	Gas well in Mississippian rock (75,000)
7	Bristol Natural Gas Co.	M. Sproles No. 6	1579′	4103′	Gas well in Mississippian rock (1,000,000)
8	Davis Elkins (Bristol Natural Gas Co.)	J. R. Smith Heirs No. 2	1561′	5650′	Abandoned (Gas shows in Mississippian and Devonian rock)
9	Holston Oil & Gas Co.	B. Barker	—	2500′±	Dry hole (rig burned)
10	Holston Oil & Gas Co.	W. E. Leonard	—	2600′±	Dry hole
11	Early Grove Gas Co.	Ridgway No. 1	1540′	—	Drilled 1980
12	Early Grove Gas Co.	McMurry No. 1	1544′	—	Drilled 1980
13	Early Grove Gas Co.	Bondurant No. 1	1537′	—	Drilled 1980
14	Early Grove Gas Co.	Dorton No. 1	1499′	—	Drilled 1980
15	Early Grove Gas Co.	Harless No. 1	1518′	—	Drilled 1980

Abbreviations: TD, total depth; cfgpd, cubic feet of gas per day; OWDD, old well drilled deeper.

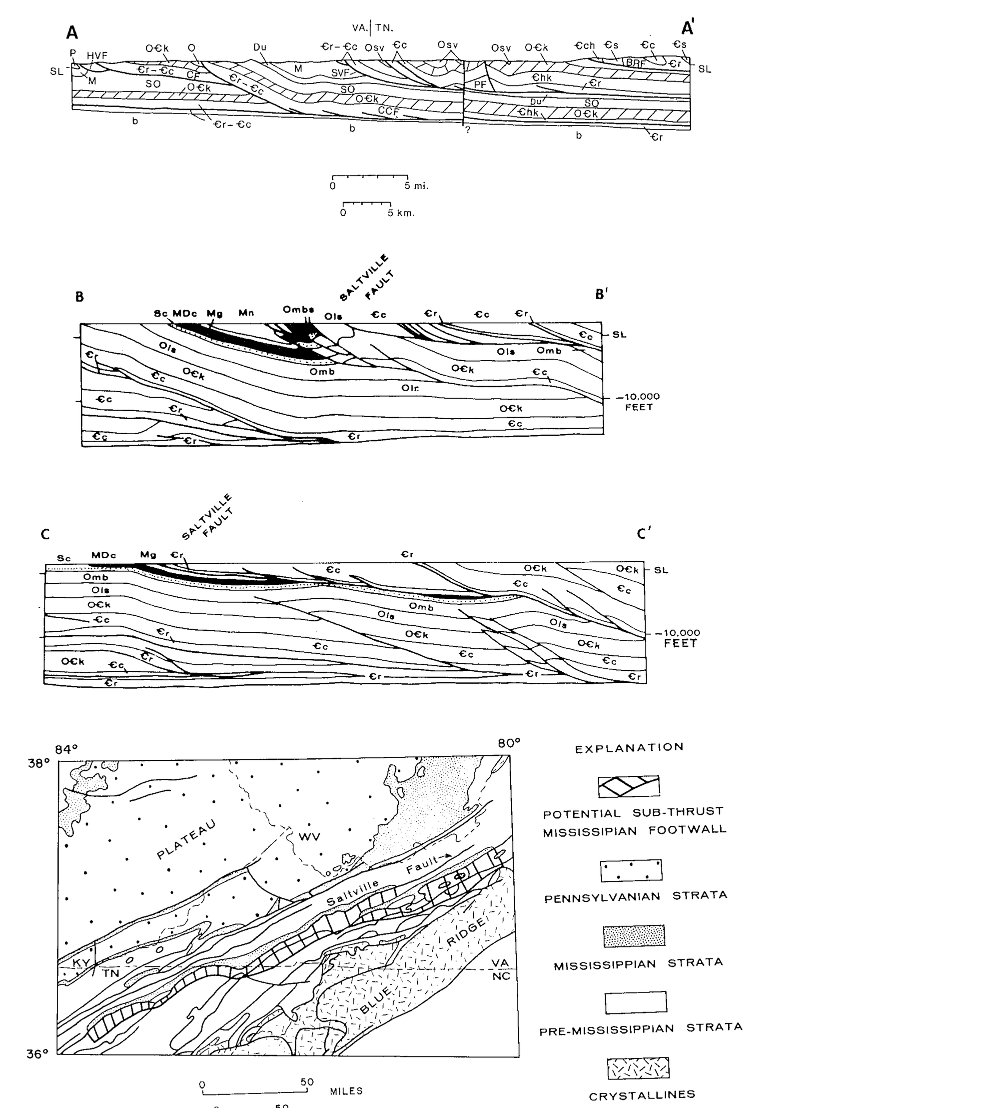

FIGURE 2-5. Areas potentially suitable for preservation of Mississippian strata beneath the Saltville and Pulaski thrust sheets in Southwestern Virginia and northeastern Tennessee.

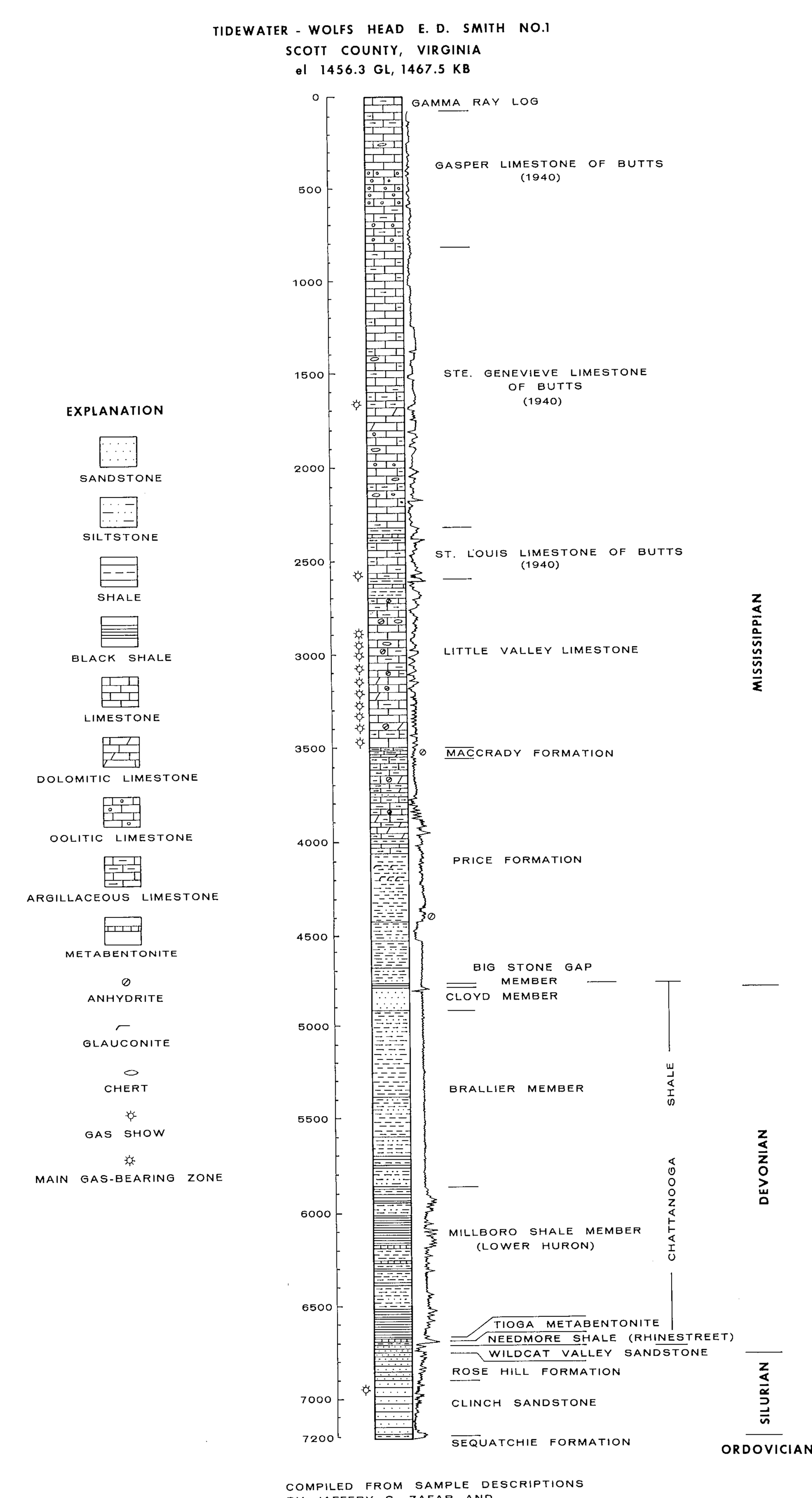

Figure 2-4. Columnar section of Tidewater-Wolfs Head, E. D. Smith No. 1, Early Grove gas field.

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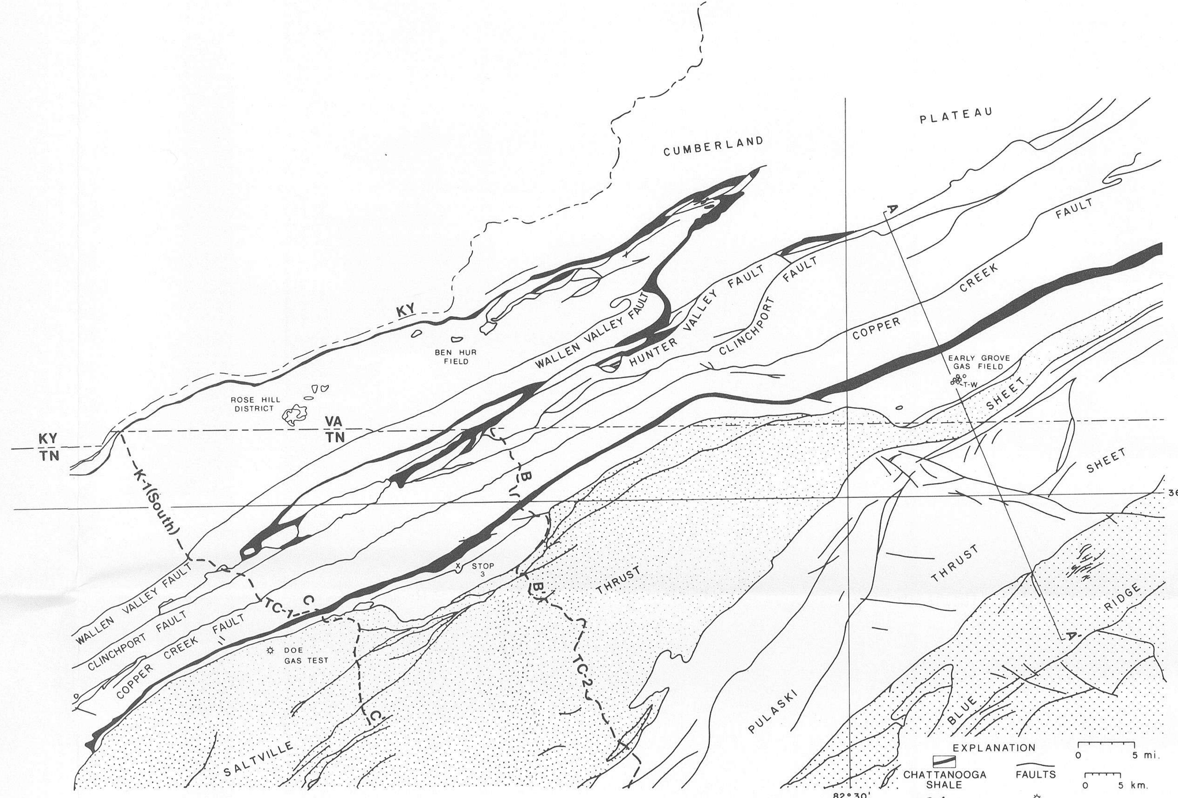

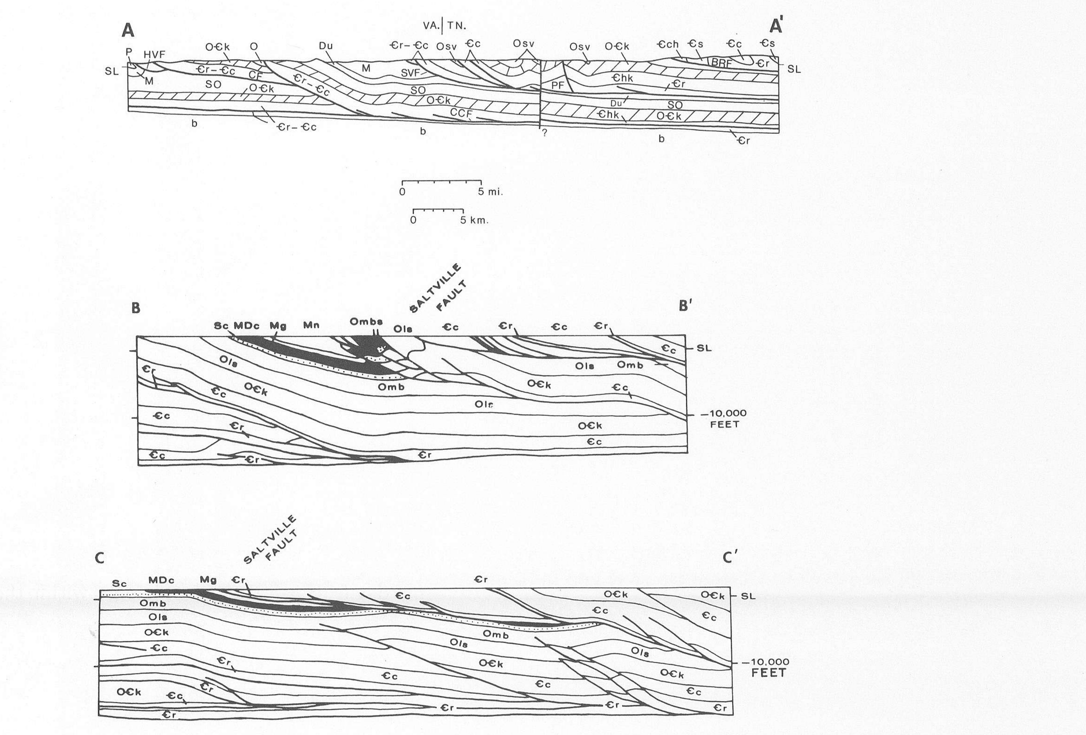

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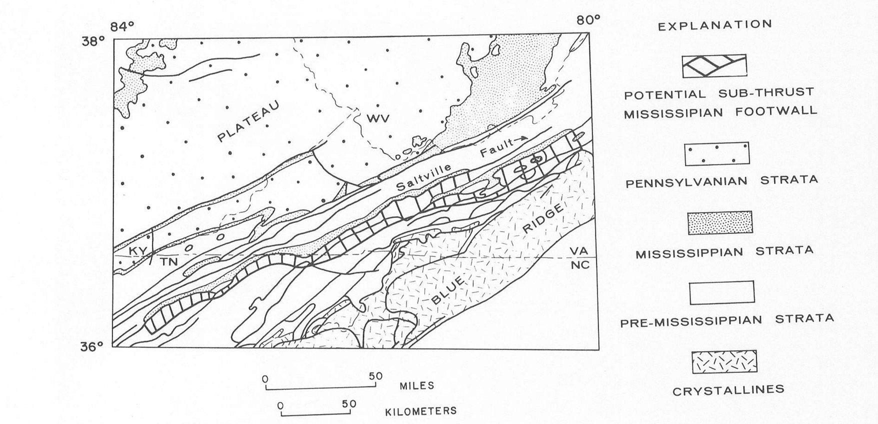

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16	Trans-State Oil Ltd.	Bruce Riggs No. 1	2140′	Dry hole, 1970 Oil show in Silurian (Clinch) W-2488
17	Castle and Jenkins	W. B. Osborne No. 1	4861′ in Ordovician	Dry hole, 1950 Gas show (personal communication) W-44
18, 19, 20	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 1	759′ (?)	Abandoned, 1961-2 W-691
	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 2	—	Abandoned; (20′ from No. 1)
	Appalachian Oil & Mineral Development Co., Inc.	A. R. Harris No. 3	3912′	Dry hole; (near No. 1 & No. 2) W-987
21	Appalachian Oil & Mineral Development Co., Inc.	M. Robinette No. 1	1389′ (?)	Dry hole, 1962 W-640
22	C. E. Deaton	M. H. Snodgrass No. 1	1706′ in Cambrian (Copper Ridge)	Oil show in Ordovician (Chepultepec) Dry hole, 1947 W-116
23	Cedar Valley Oil Co.	D. C. McClure No. 1	3250-3400′ (?)	Gas show, in Ordovician (Trenton?) Dry hole, 1915
24	Clarence Ellison (K. R. Wilson)	Charles Phipps No. 1	1902′ in Silurian (Clinch)	Dry hole, 1947 W-107
25	R. R. Murray	Anthony Ely No. 1	2532′ in Ordovician (Hardy Creek)	Gas and oil shows; flowed gas from Ordovician (Reedsville) at about 100,000 cfgpd Abandoned, 1947 W-61
26	Lee Oil Drilling Co.	D. L. Graybeel No. 1	7209′ in Ordovician	Tested 2 BOPD from Ordovician (Moccasin) Dry hole, 1977 W-5227
27	Robert Vorhees	Mill Davis No. 1	4406′ in Ordovician (Mascot)	Oil shows in Ordovician (Trenton) Dry hole, 1947 W-75
28	H. & R. Oil Co.	Grant Smith No. 1	2188′ in Ordovician (Hardy Creek)	Oil show in Ordovician (Trenton) Dry hole, 1948 W-145
29	K. R. Wilson	E. C. H. Rosenbaum No. 1	1456′ in Silurian (Clinton)	Abandoned, 1947 W-153
30	K. R. Wilson	O. Cavins No. 1	2001′ in Ordovician (Chepultepec)	Dry hole, 1947 W-98
31	Shell Oil Co.	L. S. Bales No. 1	8020′ in Cambrian (Copper Ridge)	Dry hole, 1965 Gas shows in Ordovician and Cambrian Dead oil shows W-1273
32	Virginia Lee Oil Co. (Fitch *et al.*)	E. M. Brooks No. 1	4079′ in Ordovician (Eggleston)	Gauged 225,000 cfgpd gas, from Silurian (Hancock) gas show in Clinch, oil shows in Ordovician Abandoned, 1945 W-80.
33	Rouge Oil Co.	Henley Sutton No. 1	4000′ (OWDD)	Gas show Dry hole, 1947, 1954 W-118
34	Johnson, Head, & Gilmore	Billy Parkey No. 1	2650′	Show of "oily gas" Abandoned, 1929

Abbreviations: TD—total depth of well; W-136, Virginia Division of Mineral Resources Well Sample Number; BOPD—barrels of oil per day; cfgpd—cubic feet of gas per day; OWDD—old well drilled deeper.

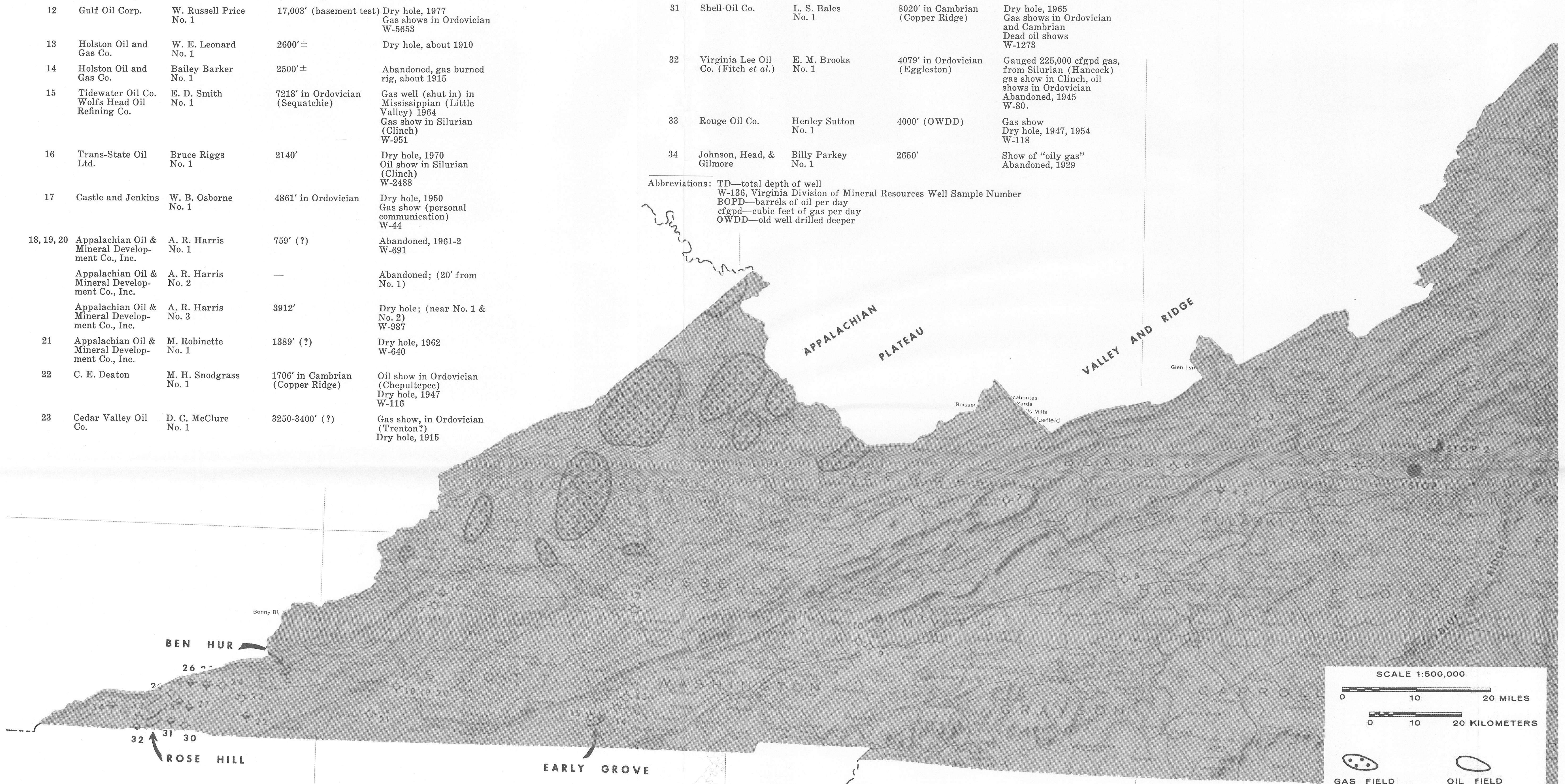

FIGURE 2-1. Location map for Southwestern Virginia, showing *Stops 1* and *2*, significant oil and gas tests, and oil and gas fields (compiled by D. C. Le Van).

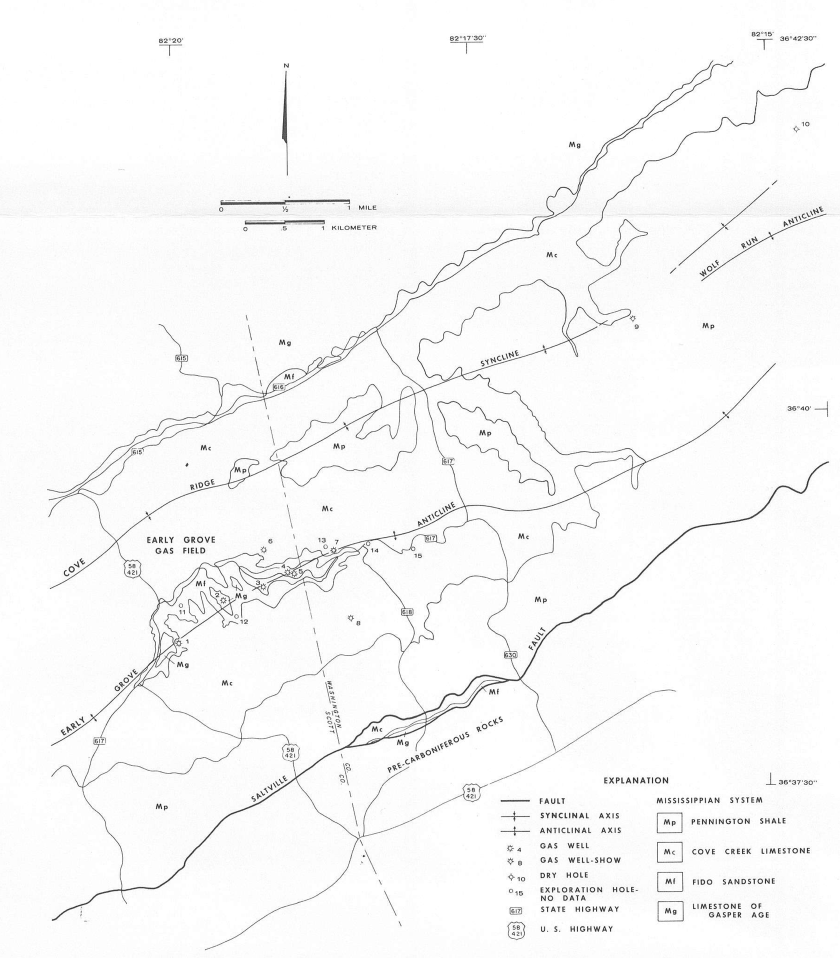

FIGURE 2-3. Geologic map and well locations in Early Grove gas field (After Averitt, 1941).

TABLE 2—Well data from the Early Grove Area, Scott and Washington counties, Virginia (compiled by G. P. Wilkes). Well numbers correspond to those on Figure 2-3.

Map Well No.	Operator	Property and Well No.	El. (ft.)	TD (ft.)	Remarks (cfgpd)
1	Bristol Natural Gas Co.	H. A. Miller No. 1 (8)	1562′	5862′ (OWDD)	Gas well (127,000 in Mississippian rock; 30,000 in Devonian rock)
2	Davis Elkins (Bristol Natural Gas Co.)	C. B. & J. H. Hunsucker No. 1 (3)	1507′	3721′	Gas well (abandoned) in Mississippian rock (200,000)
3	Davis Elkins (Bristol Natural Gas Co.)	E. S. Ridgeway No. 1	1461′	3613′	Gas well in Mississippian rock (1,750,000)
4	Tidewater-Wolf's Head	E. D. Smith No. 1	1456′	7218′	Shut in gas well (gas show in Mississippian rock)
5	Bristol Natural Gas Co.	E. D. Smith No. 5	1459′	3435′	Gas well in Mississippian rock (1,500,000)
6	Davis Elkins (Bristol Natural Gas Co.)	G. W. Fleenor No. 4	1511′	3854′	Gas well in Mississippian rock (75,000)
7	Bristol Natural Gas Co.	M. Sproles No. 6	1579′	4103′	Gas well in Mississippian rock (1,000,000)
8	Davis Elkins (Bristol Natural Gas Co.)	J. R. Smith Heirs No. 2	1561′	5650′	Abandoned (Gas shows in Mississippian and Devonian rock)
9	Holston Oil & Gas Co.	B. Barker	—	2500′±	Dry hole (rig burned)
10	Holston Oil & Gas Co.	W. E. Leonard	—	2600′±	Dry hole
11	Early Grove Gas Co.	Ridgway No. 1	1540′	—	Drilled 1980
12	Early Grove Gas Co.	McMurry No. 1	1544′	—	Drilled 1980
13	Early Grove Gas Co.	Bondurant No. 1	1537′	—	Drilled 1980
14	Early Grove Gas Co.	Dorton No. 1	1499′	—	Drilled 1980
15	Early Grove Gas Co.	Harless No. 1	1518′	—	Drilled 1980

Abbreviations: TD, total depth; cfgpd, cubic feet of gas per day; OWDD, old well drilled deeper.

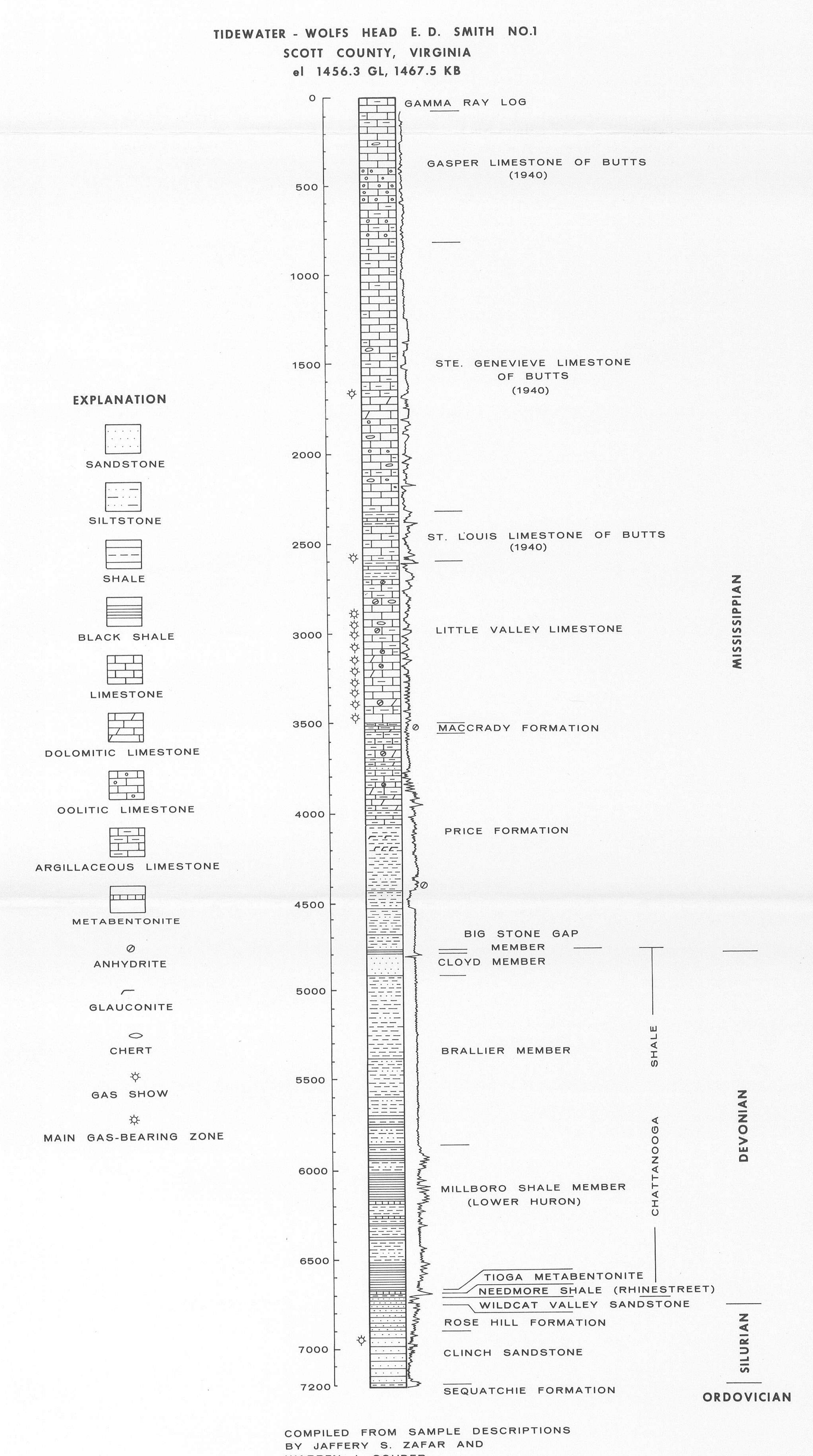

Figure 2-4. Columnar section of Tidewater-Wolfs Head, E. D. Smith No. 1, Early Grove gas field.

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Part C. SALTVILLE FAULT FOOTWALL STRUCTURE AT STONE MOUNTAIN, HAWKINS COUNTY, TENNESSEE. STOP 3A

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 23
1980

GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 5 (of 6)

By Robert C. Milici

GREENDALE SYNCLINE

The stratigraphy of the Grainger Formation in the Greendale syncline was studied by Sanders (1952) and by Hasson (1972, 1973). Their work was summarized by Milici and others (1979): "The type area of the Grainger is in the Greendale syncline, along a low ridge called Pine Mountain which is east of Clinch Mountain. The Grainger was studied there by Sanders (1952) and by Hasson (1972, 1973). Sanders (1952) divided the Grainger into four lithologic members, a basal member, a lower sandstone member, a middle siltstone-shale member, and an upper sandstone member. The basal member, which is 200-300 feet (61-91 m) thick, consists of dark-gray argillaceous shale and olive-gray siltstone, thin beds of fine-grained sandstone, and a little limestone. The lower sandstone member ranges from 50 to 200 feet (15.2 to 61 m) in thickness along the Greendale syncline in Tennessee. The unit consists of very fine grained light-gray sandstone and some pebble conglomerate. The middle member of the Grainger consists of 400 to 500 feet (122 to 152 m) of gray shale and olive-gray siltstone; two glauconite zones are in the upper part. Except for the glauconite beds, the middle and basal members are lithologically similar. The upper sandstone member of the Grainger consists of as much as 150 feet (45.7 m) of very fine grained to coarse-grained feldspathic, medium-gray sandstone and some interbedded olive-gray silty shale. Cross bedding is common, and the upper part of the member contains pebble conglomerate of vein quartz, quartzite, feldspar, and slate.

"Hasson (1972, 1973) restricted the Grainger Formation in the Greendale syncline to the upper three members of Sanders (1952) and correlated the basal member with most of the Big Stone Gap Member of the Chattanooga Shale in southwestern Virginia. Hasson (1973) provided two measured sections of the Grainger (restricted), one at the type section in Grainger County, and another in Hawkins County, which he designated as the standard reference section for the formation. Depending upon the assignment of the basal member of Sanders (1952), the Grainger is either 552 or 768 feet (168 or 234 m) thick at the standard reference section. Hasson (1972, 1973) concluded that the Grainger was of Kinderhook-Osage age, on the basis of brachiopods, bryozoans, and crinoid columnals that he studied."

For simplicity the Grainger units of Sanders (1952) are designated herein as units a, b, c and d. Units b and c, the lower sandstone member and the middle member of the Grainger of Sanders (1952), appear to be the only units of the Grainger exposed along Tennessee Highway 66 on the northwest side of Stone Mountain. The complexity of the structure there, however, makes these stratigraphic identifications uncertain.

Sanders (1952) interpreted the structures in this area as a complex of thrust faults and deeply extending normal faults. Our work here and elsewhere has shown that the extensional faults are related to movement on underlying decollements and in many places extensional faults are an intimate part of the decollement model. On the basis of these faults and the model, we interpret the complex structures in the footwall of the Saltville fault along Stone Mountain to have resulted primarily from imbrication of blocks of strata along the toe of the ramp-derived horse block. Imbrication occurred where the dip of the Saltville fault flattened in the shaly beds near the top of the ramp (Figure 5-1, cross section DD′).

STOP 3A—Stone Mountain Gap

Beds in the hanging wall above the gap are Chattanooga Shale and Clinch Sandstone; the Chattanooga is sharply overturned and is structurally overlain by the Clinch. Some of the Grainger (footwall beds) may be overturned, but stratigraphic sequences and some minor folds are evidence that most of the beds are right-side up. (Figure 5-2).

At Stone Mountain Gap, Grainger sandstone member b is thrust over the glauconite-bearing member, unit c. Although the larger faults are thrusts and the tectonic regime is compressional, almost all of the minor faults are extensional. Argillaceous beds are deformed near most faults and in places the beds are complexly folded. Near the middle of the cut, unit b appears to be faulted down through unit c by a comparatively large-scale extensional fault. Unit b is underlain by a low angle thrust zone, some 10 to 20 feet (3 to 6 m) thick, that contains folded and faulted fine-grained sandstones, siltstones and some black carbonaceous shale. The shale at the base of the sandstone may be representative of the Chattanooga. Beneath the low angle thrust, units b and c are again juxtaposed by extensional and contractional faults. The fault patterns in this exposure, as in lower exposures, suggest that deformation within the Grainger migrated sequentially upward.

REFERENCES

Hardeman, W. D., Miller, R. A., and Swingle, G. D., 1966, Geologic Map of Tennessee: Scale 1:250,000.

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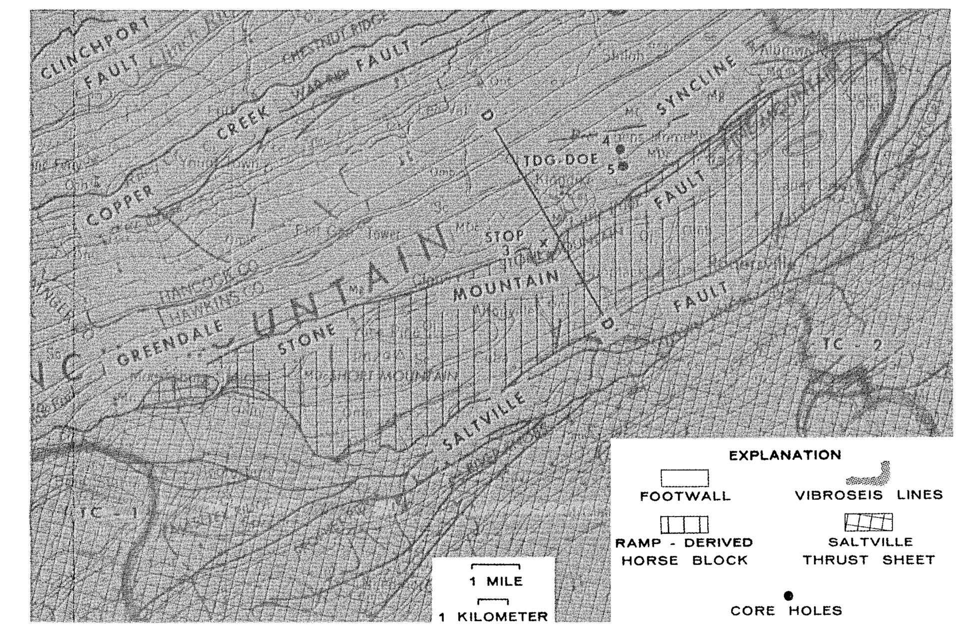

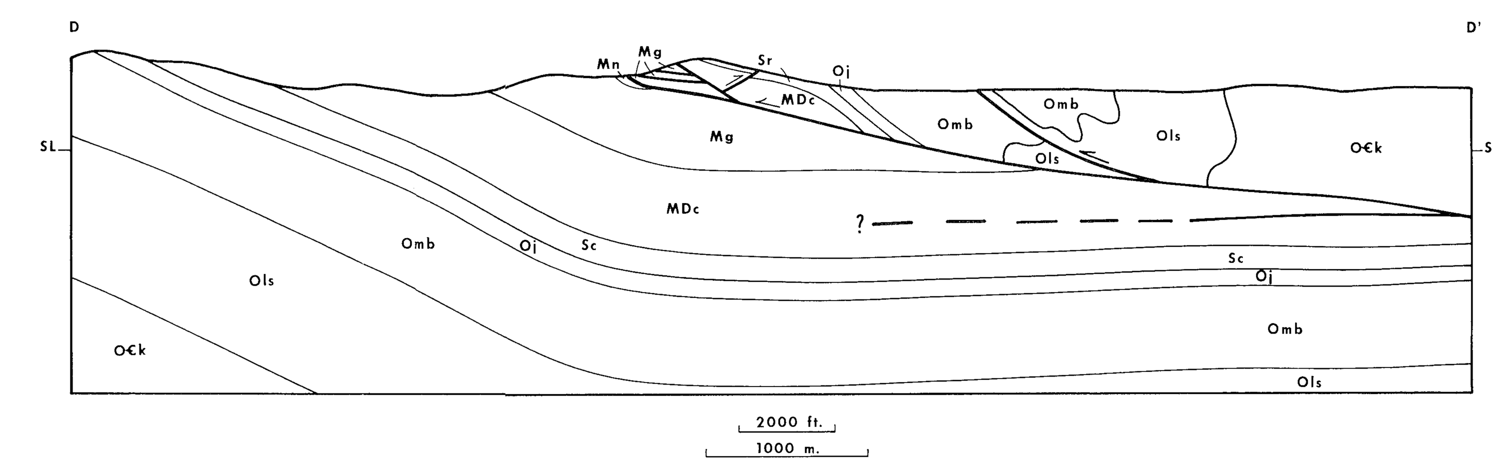

FIGURE 5-1: Geologic map and cross section of the Greendale syncline at Stop 3; map enlarged from Hardeman, Miller and Swingle (1956); Cross section modified from Sanders (1952) Cross section symbols O€K - Knox Group; Ols - Ordovician limestones; Omb - Martinsburg Shale; Oj - Juniata Formation; Sc-Clinch Sandstone; MDc - Chattanooga Shale, Mg - Grainger Formation; Mn - Newman Limestone

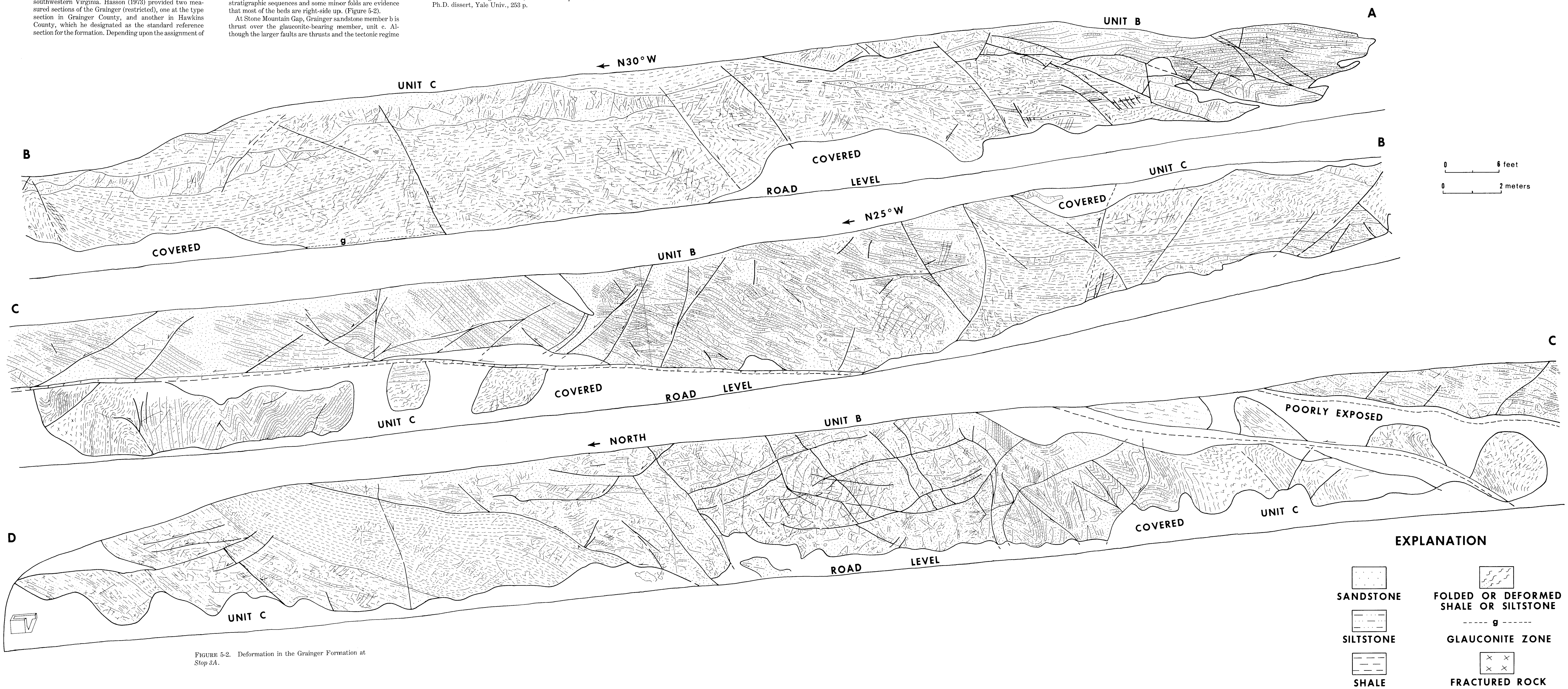

FIGURE 5-2. Deformation in the Grainger Formation at Stop 3A.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

Part C. SALTVILLE FAULT FOOTWALL STRUCTURE AT STONE MOUNTAIN, HAWKINS COUNTY, TENNESSEE. STOP 3A

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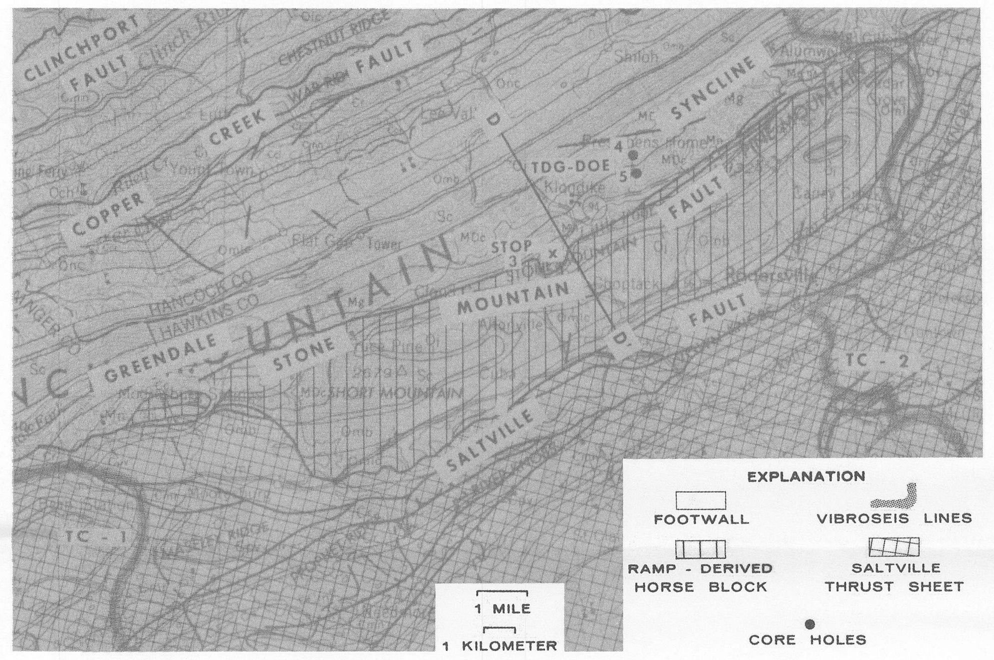

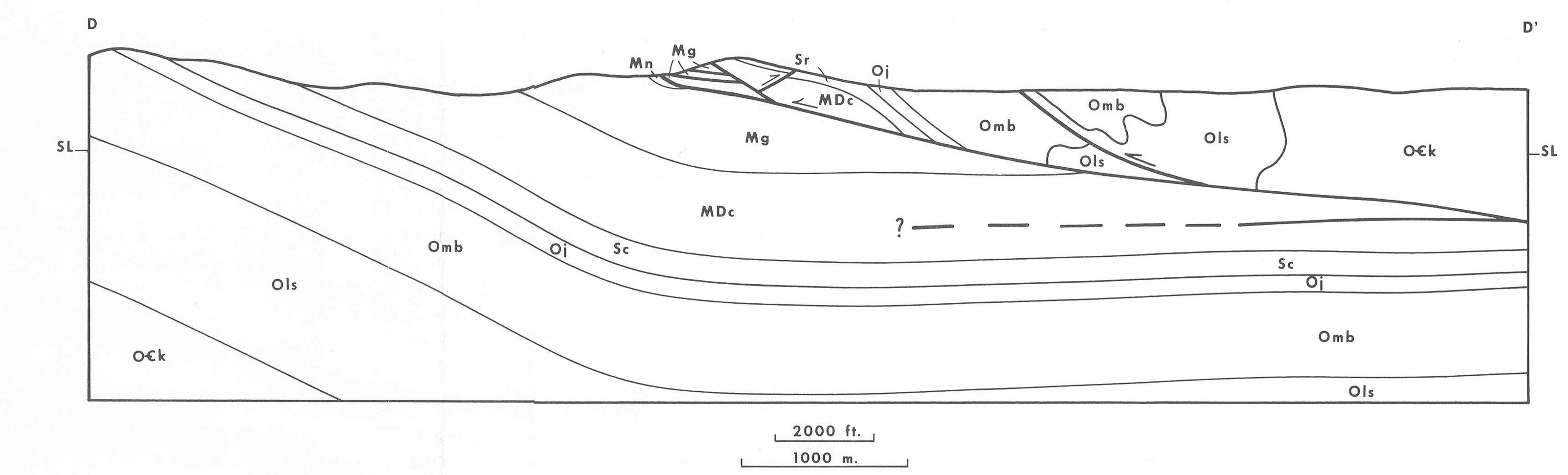

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FIGURE 5-2. Deformation in the Grainger Formation at *Stop 3A*.

COMMONWEALTH OF VIRGINIA
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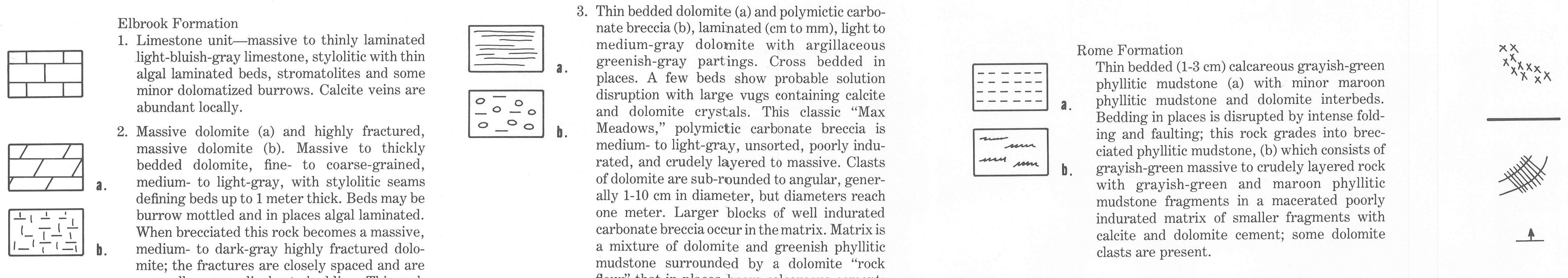
Part B. DEFORMATION IN THE HANGING WALL OF THE PULASKI THRUST SHEET NEAR IRONTO, MONTGOMERY COUNTY, VIRGINIA (Cont.). STOP 2

By A. P. Schultz and M. J. Bartholomew

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 23
1980

GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 4 (of 6)



Elbrook Formation

1. Limestone unit—massive to thinly laminated light-bluish-gray limestone, stylolitic with thin algal laminated beds, stromatolites and some minor dolomatized burrows. Calcite veins are abundant locally.
2. Massive dolomite (a) and highly fractured, massive dolomite (b). Massive to thickly bedded dolomite, fine- to coarse-grained, medium- to light-gray, with stylolitic seams defining beds up to 1 meter thick. Beds may be burrow mottled and in places algal laminated. When brecciated this rock becomes a massive, medium- to dark-gray highly fractured dolomite; the fractures are closely spaced and are generally perpendicular to bedding. This rock weathers to small rectangular fragments.
3. Thin bedded dolomite (a) and polymictic carbonate breccia (b), laminated (cm to mm), light to medium-gray dolomite with argillaceous greenish-gray partings. Cross bedded in places. A few beds show probable solution disruption with large vugs containing calcite and dolomite crystals. This classic "Max Meadows," polymictic carbonate breccia is medium- to light-gray, unsorted, poorly indurated, and crudely layered to massive. Clasts of dolomite are sub-rounded to angular, generally 1-10 cm in diameter, but diameters reach one meter. Larger blocks of well indurated carbonate breccia occur in the matrix. Matrix is a mixture of dolomite and greenish phyllitic mudstone surrounded by a dolomite "rock flour" that in places bears calcareous cement; includes fragments less than 1 cm.

Rome Formation

Thin bedded (1-3 cm) calcareous grayish-green phyllitic mudstone (a) with minor maroon phyllitic mudstone and dolomite interbeds. Bedding in places is disrupted by intense folding and faulting; this rock grades into brecciated phyllitic mudstone, (b) which consists of grayish-green massive to crudely layered rock with grayish-green and maroon phyllitic mudstone fragments in a macerated poorly indurated matrix of smaller fragments with calcite and dolomite cement; some dolomite clasts are present.

En echelon calcite veins

Faults

Cleavage

Direction of younger beds

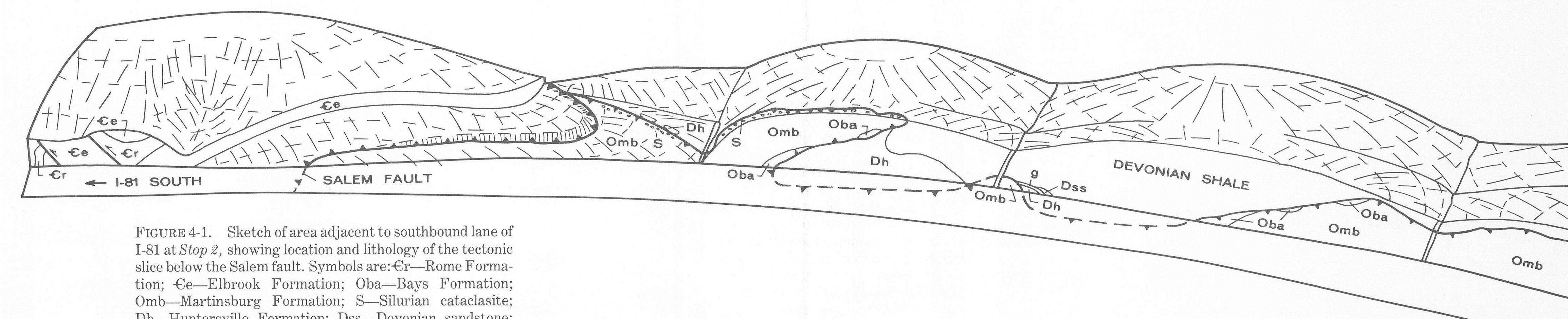


FIGURE 4-1. Sketch of area adjacent to southbound lane of I-81 at *Stop 2*, showing location and lithology of the tectonic slice below the Salem fault. Symbols are: €r—Rome Formation; €e—Elbrook Formation; Oba—Bays Formation; Omb—Martinsburg Formation; S—Silurian cataclasite; Dh—Huntersville Formation; Dss—Devonian sandstone; g—glauconite. Fault teeth are on upper plate.

FIGURE 4-2. Folded and faulted Elbrook and Rome formations along north side of I-81 at *Stop 2*.

ROAD LOG (continued)

Interstate 81
Milepost
mileage

128.20 Turn left onto ramp for Interstate 81 south.

128.0 Milepost marker.

127.9 Concretion-bearing black shales of the Devonian-age Millboro Formation on the footwall of the Salem fault are exposed in outcrops on the right.

127.65 The approximate contact between the overlying Martinsburg Formation of the tectonic slice and the Millboro Formation (Figure 3-1).

127.3 *Stop 2.* Stop directly opposite exposure of the Salem fault near the northbound lanes of Interstate 81. The slopes on the southbound side of highway are diagrammatically illustrated in Figure 4-1. The entire grassy slope above the southbound lane was the site of a large landslide onto the highway when the Salem fault was cut through during construction for Interstate 81. Figure 4-1 shows the distribution of the tectonic slices of Silurian and Ordovician rocks beneath the Salem fault. Figure 4-2 is along the extreme southwestern end of the area shown in Figure 4-1. A small amount of siliceous cataclasite is along the leading edge of the fault where it is juxtaposed over Hunterville chert and associated glauconitic sandstones (Figure 4-3); however, rocks of the Martinsburg and Bays formations form most of the tectonic slice. Structural data for *Stop 2* are presented in Figure 4-4; analyses include orientation of bryozoan colonies, examples of which are shown in Figure 4-5. Common features of the polydeformed terrane of the Pulaski-Salem fault system are small-scale folds (Figure 4-6) and calcite-filled, *en echelon* fractures (Figure 4-7). As indicated by structural data (Figure 4-4D) gathered at the Figure 4-2 locality, the fractures do not appear to be related to the F2/Salem thrusting event. Moreover, from the truncation of the calcite-filled fractures by injection-breccia (Figure 4-8) it is inferred that the fractures probably are related to the earlier deformation, which produced the F_1 folds. It is interesting to note that the narrow injection breccia zone is also the locus of high-angle brittle faulting which cuts through the breccia zone (Figure 4-9).

126.95 Milepost marker, end of cuts seen at *Stop 2*.

123.25 A large fold in the Rome Formation is visible across the drainage on the north side of the highway.

121.4 Breccia formed along a thrust surface is visible beneath a thin broken formation zone (Figure 4-10).

121.85 Location of *Stop 1*.

120.25 Overturned section of the Elbrook Formation exposed for next 0.6 miles on both sides of the highway. Large stromatolites are near the south end of the cut, about 25 feet (8 m) above the road level. Abundant extensional and contractional faults (Figure 4-11) are visible in the exposures.

119.3 Leave the polydeformed terrane of the Pulaski-Salem thrust sheets and enter the area of the Christiansburg window.

118.85 Exit ramp for U. S. Highway 11 on right (Interchange 37 for Christiansburg and Blacksburg).

Proceed south on Interstate 81 to Tennessee; enter Tennessee and at milepost 75, turn off at exit 74B and turn right (west) onto U.S. Highway 11W. Follow U.S. Highway 11W for 48 miles (77 km) through Kingsport to the Rogersville bypass. Turn right (northwest) onto Tennessee Highway 66; follow Tennessee Highway 66 for 8.3 miles (13 km) to *Stop 3* at crest of Stone Mountain.

The field trip route from Bristol to Kingsport (U.S. Highway 11) generally cuts across strike of beds on the hanging wall of the Pulaski fault. Near Kingsport the route enters the Saltville thrust sheet and traverses the Sevier Shale (Ordovician) around the northeast end of the Bays Mountain synclinorium. It then generally follows the Sevier-Knox contact south to Rogersville. Near Rogersville the field trip route again cuts across strike and traverses the Stone Mountain horse block to *Stop 3* in foot wall rocks of the Saltville thrust.

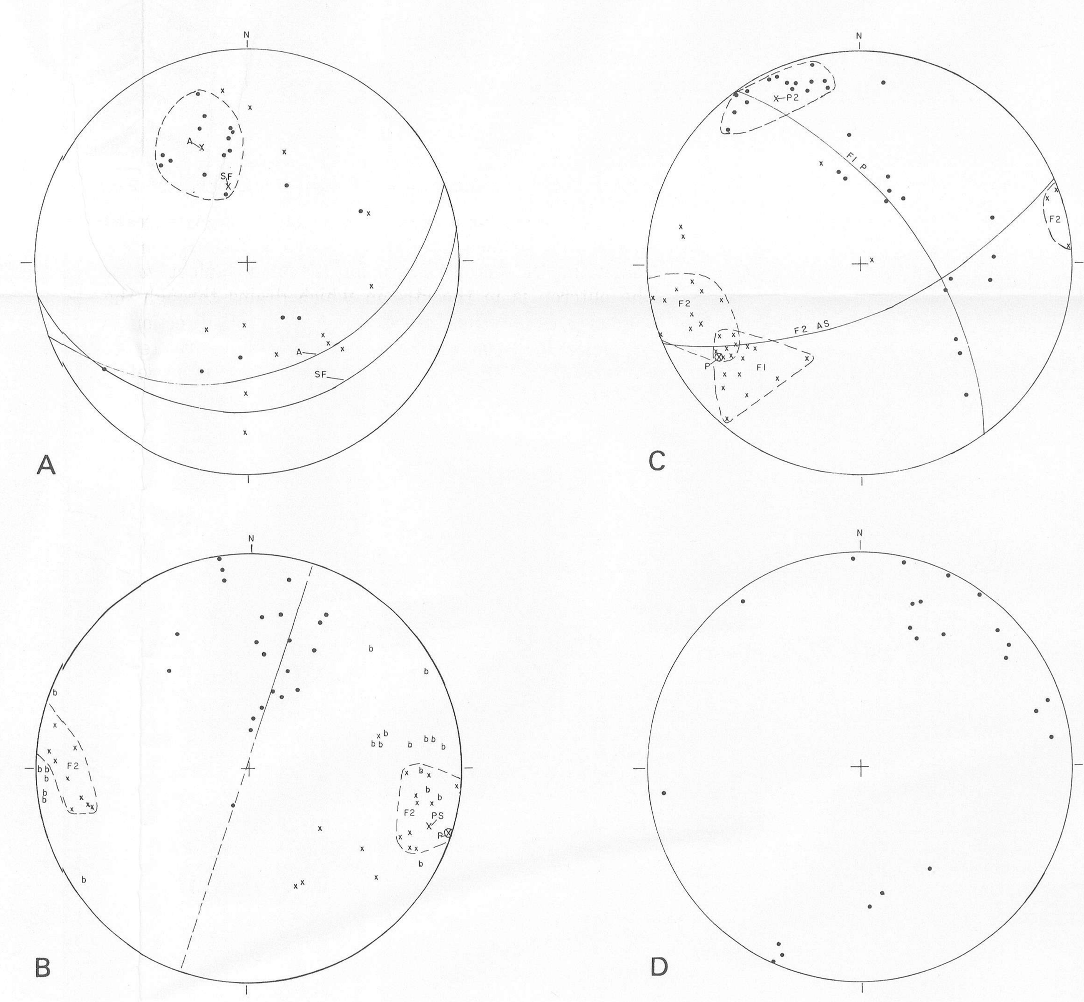


FIGURE 4.4 Lower hemisphere Schmidt net projections of structural data collected at *Stop 2*.

A. Plot of poles to fault surfaces (dots) and slickensides (lineations) on these surfaces (x's) in the Martinburg Formation at *Stop 2*. The large X labeled A represents the approximate geometric center of pole concentration and the surface labeled A is the corresponding plane of this point; note the close similarity in orientation of plane A and the actual Salem fault surface (labeled SF) as measured on the south side of the Interstate. The large X labeled SF is the pole to the Salem fault; also note that the slickensides reflect that movement along the Salem fault and associated minor faults was in an approximate north-south direction.

B. Plot of fold axes, poles to axial surfaces, and elongation direction of boudins in Martinsburg Formation at *Stop 2*. Fold axes (x's) indicate that F_2 folds are generally east-west and subhorizontal as reflected in the areas labeled F_2. Some axes plot outside of these areas and reflect later, open folds and warps associated with high angle faults. The poles to axial surfaces (dots) have an approximate spread in orientation of 70°. The poles lie along a near vertical plane, reflecting a near horizontal axis of rotation (X labeled P) that falls within the F_2 area. This horizontal orientation is interpreted to mean that during the F_2/Salem thrusting event, early-formed folds were rotated (perhaps during transport of this tectonic slice) by forces that developed other, later-formed folds. Boudin (b) formed in limestone beds of the Martinsburg Formation are evidence that the intermediate axis of the strain ellipse for the F_2/Salem thrusting event was oriented approximately east-west. A cluster of several bryozoan colonies (Figure 4-5) were found to have their long axes (PS) generally parallel to F_2 fold axes and boudin. These bryozoan specimens appear to be examples of one of the special cases discussed by Ramsey (1967, p. 220-221) in which the original short axis of the bryozoan colonies were perpendicular to bedding. Because the greatest tectonic extension coincided with this direction, the long axes of the deformed colonies is parallel to a fold axis.

C. Plot of fold axes and poles to axial surfaces measured in the Elbrook Formation and Rome Formation at *Stop 2*. Axes (x's) of F_2 folds, areas labeled F_2, from the hanging wall of the Salem thrust reflect an east-west, subhorizontal trend as also shown in Figure 4-4B. Moreover, the geometric center (x labeled P2) of the concentration of poles to these axial surfaces shows an average axial surface (labeled F_2, AS) dipping steeply southeast and striking approximately N65°E. F_1 axes (x's in area labeled F_1) form a cluster of points which represent a shallow, southwesterly plunge. Poles to the F_1 axial surfaces fall along a surface with a steep, northeasterly dip (labeled F_1P) and with an axis of rotation (X labeled P) that falls within the cluster of points representing F_2 axes. This correspondence is evidence that F_1 axial surfaces are folded about F_2 axes and that at this locality F_2 and F_1 axes are almost coaxial. These relationships are illustrated in Figure 4-6.

D. Plot of poles to calcite-filled veins occurring in *en echelon* fractures in the Elbrook Formation at *Stop 2*. These poles are interpreted as lying primarily in the direction of maximum elongation in the strain field, which lies in a northeast-southwest direction. This direction does not conform with the expected direction of maximum elongation as deduced from Figure 4-4A, B, C for the F_2/Salem thrusting event; hence the calcite-filled tension fractures are probably related to the earlier deformational event.

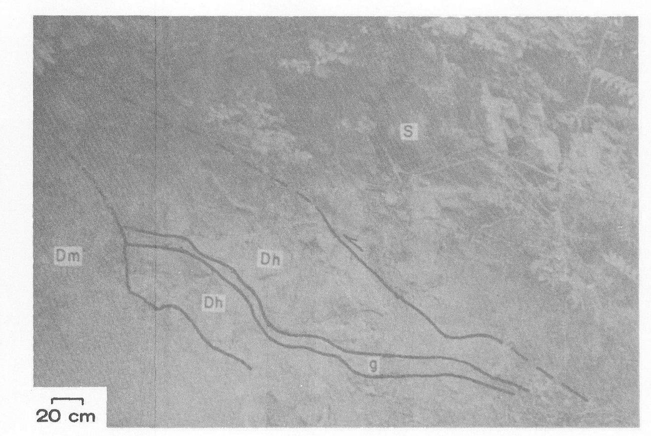


FIGURE 4-3. Siliceous cataclasite derived from Silurian strata of the tectonic slice at *Stop 2*. Photo was taken along drainage ditch at east side of the grassy landslide area. The cataclasite lies structurally above rocks of the Millboro and Huntersville formations of the Salem synclinorium. The cataclasite, as well as the structurally overlying Martinsburg and Bays formations, was derived from the footwall block, a part of the overturned southeastern limb of the Salem synclinorium. Tectonic slices similar to the ones seen here are found along both the Salem and Pulaski faults.

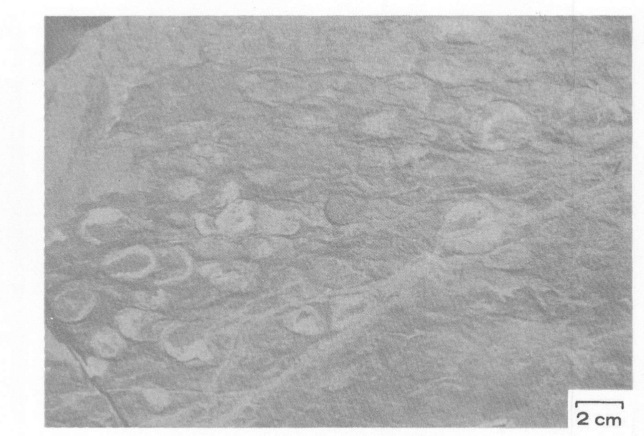


FIGURE 4-5 Strain elongation of colonial byozoa exposed on a bedding surface in the Ordovician Martinsburg Formation, within the tectonic slice below the Salem fault at *Stop 2*. The outcrop is in the stream which drains through the median strip of the Interstate. Elongation direction is parallel to fold axes of F2 folds and probably is related to emplacement of the Salem fault during Alleghanian deformation.

FIGURE 4-6 Typical small-scale F_1 and F_2 folds in the Elbrook shaly dolomites of the polydeformed Pulaski thrust sheet. Here, on a small scale the isoclinal fold-form of F_1 folds contrasts strongly with the more open asymmetric "s" shaped form of the F_2 folds associated with Alleghanian deformation. Small faults and minor brecciation in folds help take care of "space problems" in forming the F_1 type folds.

FIGURE 4-7. Sigmoidal *en echelon* calcite-filled veins in thick-bedded limestone of the Elbrook Formation at *Stop 2*. Photograph was taken near the center of the outcrop profile. Most, if not all, of the calcite-filled veins here appear to be fillings of several sets of *en echelon* fractures and we interpret the poles to the veins to be parallel to the direction of maximum elongation.

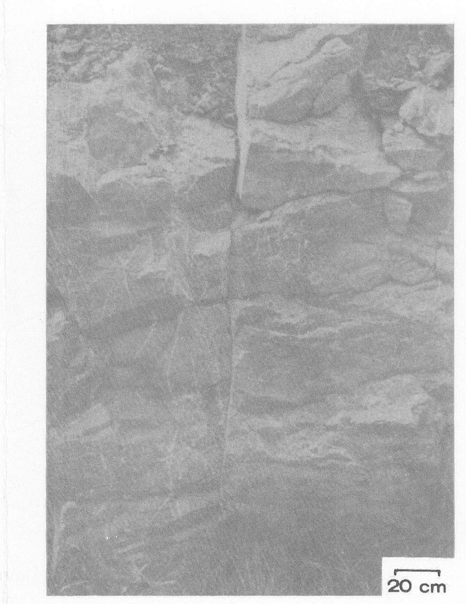


FIGURE 4-9. A later-stage fault with slickensides cutting through the breccia zone (Figure 4-8), and also following it. These relationships indicate that the fracture probably remained a zone of weakness even after the breccia filled the original fracture.

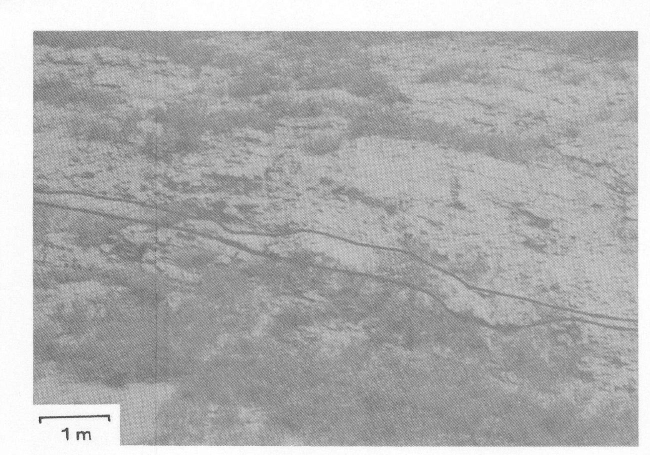


FIGURE 4-10 Photograph of south-facing cut of southbound lane at mile 121.4. Bedding-parallel décollement within a relatively undeformed medium-to thick-bedded sequence of limestone and dolomites in the lower part of the Elbrook Formation. The decollement consists of a 10-20 cm thick breccia at the base and an upper 30-50 cm thick zone of complexely folded and disrupted shaly dolomite. Such decollements are prevalent in the lower Elbrook and upper Rome of the Pulaski thrust sheet.

FIGURE 4-8. a. Close-up photograph of breccia within highly fractured and veined limestone of the Elbrook Formation at *Stop 2*. Photograph was taken in the area shown in Figure 4-2. Abundant dolomite clasts as well as the sharply defined linear contact suggest that the breccia was injected into an extension fracture. Breccia cuts across the calcite-filled veins.

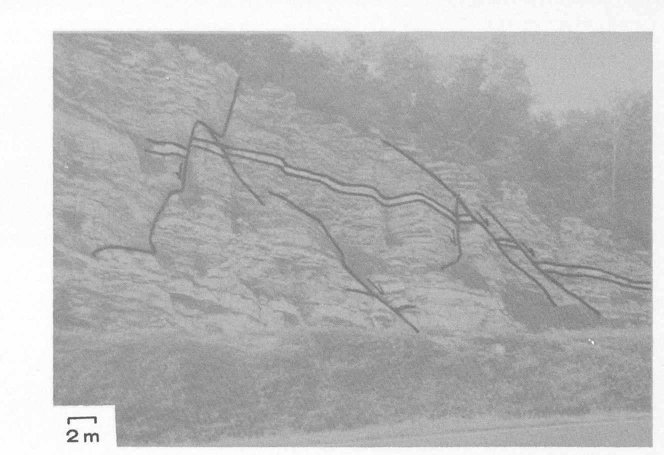


FIGURE 4-11 High angle faults in overturned, southeast dipping section of limestone and dolomite in the middle to lower part of the Elbrook Formation at I-81 mile 120.5.

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Part B. DEFORMATION IN THE HANGING WALL OF THE PULASKI THRUST SHEET NEAR IRONTO, MONTGOMERY COUNTY, VIRGINIA (Cont.). STOP 2

By A. P. Schultz and M. J. Bartholomew

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 23
1980

GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 4 (of 6)

Elbrook Formation

1. Limestone unit—massive to thinly laminated light-bluish-gray limestone, stylolitic with thin algal laminated beds, stromatolites and some minor dolomatized burrows. Calcite veins are abundant locally.

2. Massive dolomite (a) and highly fractured, massive dolomite (b). Massive to thickly bedded dolomite, fine- to coarse-grained, medium- to light-gray, with stylolitic seams defining beds up to 1 meter thick. Beds may be burrow mottled and in places algal laminated. When brecciated this rock becomes a massive, medium- to dark-gray highly fractured dolomite; the fractures are closely spaced and are generally perpendicular to bedding. This rock weathers to small rectangular fragments.

3. Thin bedded dolomite (a) and polymictic carbonate breccia (b), laminated (cm to mm), light to medium-gray dolomite with argillaceous greenish-gray partings. Cross bedded in places. A few beds show probable solution disruption with large vugs containing calcite and dolomite crystals. This classic "Max Meadows," polymictic carbonate breccia is medium- to light-gray, unsorted, poorly indurated, and crudely layered to massive. Clasts of dolomite are sub-rounded to angular, generally 1-10 cm in diameter, but diameters reach one meter. Larger blocks of well indurated carbonate breccia occur in the matrix. Matrix is a mixture of dolomite and greenish phyllitic mudstone surrounded by a dolomite "rock flour" that in places bears calcareous cement; includes fragments less than 1 cm.

Rome Formation

Thin bedded (1-3 cm) calcareous grayish-green phyllitic mudstone (a) with minor maroon phyllitic mudstone and dolomite interbeds. Bedding in places is disrupted by intense folding and faulting; this rock grades into brecciated phyllitic mudstone, (b) which consists of grayish-green massive to crudely layered rock with grayish-green and maroon phyllitic mudstone fragments in a macerated poorly indurated matrix of smaller fragments with calcite and dolomite cement; some dolomite clasts are present.

En echelon calcite veins

Faults

Cleavage

Direction of younger beds

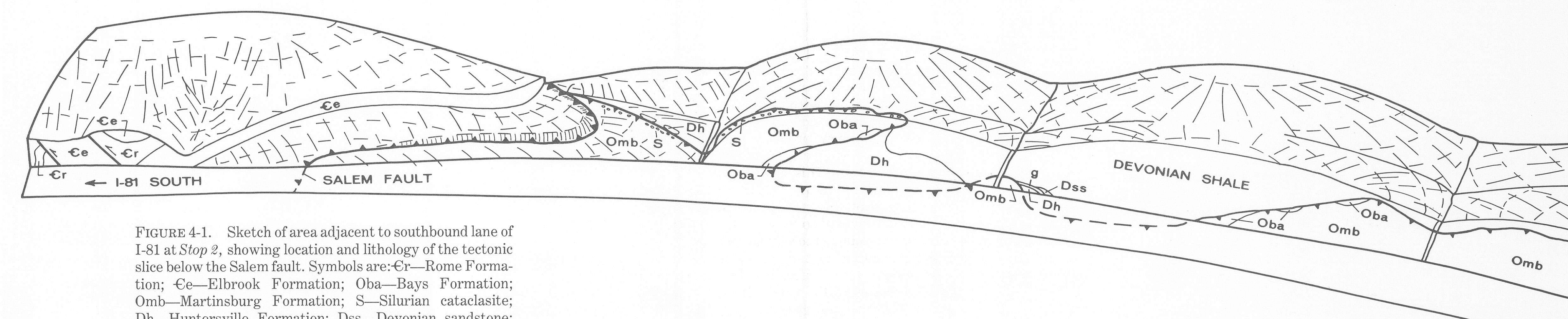


FIGURE 4-1. Sketch of area adjacent to southbound lane of I-81 at *Stop 2*, showing location and lithology of the tectonic slice below the Salem fault. Symbols are: €r—Rome Formation; €e—Elbrook Formation; Oba—Bays Formation; Omb—Martinsburg Formation; S—Silurian cataclasite; Dh—Huntersville Formation; Dss—Devonian sandstone; g—glauconite. Fault teeth are on upper plate.

FIGURE 4-2. Folded and faulted Elbrook and Rome formations along north side of I-81 at *Stop 2*.

ROAD LOG (continued)

Interstate 81
Milepost
mileage

128.20 Turn left onto ramp for Interstate 81 south.

128.0 Milepost marker.

127.9 Concretion-bearing black shales of the Devonian-age Millboro Formation on the footwall of the Salem fault are exposed in outcrops on the right.

127.65 The approximate contact between the overlying Martinsburg Formation of the tectonic slice and the Millboro Formation (Figure 3-1).

127.3 *Stop 2*. Stop directly opposite exposure of the Salem fault near the northbound lanes of Interstate 81. The slopes on the southbound side of highway are diagramatically illustrated in Figure 4-1. The entire grassy slope above the southbound lane was the site of a large landslide onto the highway when the Salem fault was cut through during construction for Interstate 81. Figure 4-1 shows the distribution of the tectonic slices of Silurian and Ordovician rocks beneath the Salem fault. Figure 4-2 is along the extreme southwestern end of the area shown in Figure 4-1. A small amount of siliceous cataclasite is along the leading edge of the fault where it is juxtaposed over Hunterville chert and associated glauconitic sandstones (Figure 4-3); however, rocks of the Martinsburg and Bays formations form most of the tectonic slice. Structural data for *Stop 2* are presented in Figure 4-4; analyses include orientation of bryozoan colonies, examples of which are shown in Figure 4-5. Common features of the polydeformed terrane of the Pulaski-Salem fault system are small-scale folds (Figure 4-6) and calcite-filled, *en echelon* fractures (Figure 4-7). As indicated by structural data (Figure 4-4D) gathered at the Figure 4-2 locality, the fractures do not appear to be related to the F_2/Salem thrusting event. Moreover, from the truncation of the calcite-filled fractures by injection-breccia (Figure 4-8) it is inferred that the fractures probably are related to the earlier deformation, which produced the F_1 folds. It is interesting to note that the narrow injection breccia zone is also the locus of high-angle brittle faulting which cuts through the breccia zone (Figure 4-9).

126.95 Milepost marker, end of cuts seen at *Stop 2*.

123.25 A large fold in the Rome Formation is visible across the drainage on the north side of the highway.

121.4 Breccia formed along a thrust surface is visible beneath a thin broken formation zone (Figure 4-10).

121.85 Location of *Stop 1*.

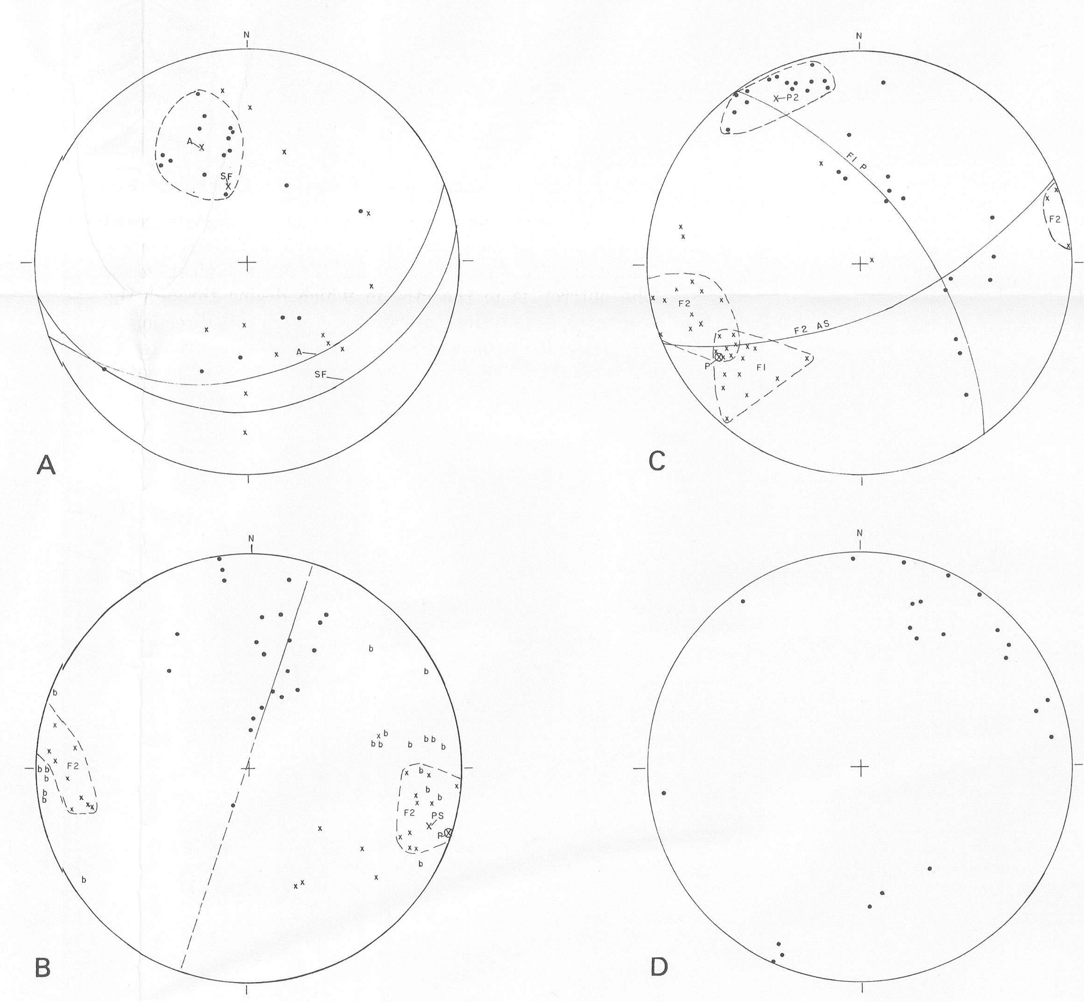
120.25 Overturned section of the Elbrook Formation exposed for next 0.6 miles on both sides of the highway. Large stromatolites are near the south end of the cut, about 25 feet (8 m) above the road level. Abundant extensional and contractional faults (Figure 4-11) are visible in the exposures.

119.3 Leave the polydeformed terrane of the Pulaski-Salem thrust sheets and enter the area of the Christiansburg window.

118.85 Exit ramp for U. S. Highway 11 on right (Interchange 37 for Christiansburg and Blacksburg).

Proceed south on Interstate 81 to Tennessee; enter Tennessee and at milepost 75, turn off at exit 74B and turn right (west) onto U.S. Highway 11W. Follow U.S. Highway 11W for 48 miles (77 km) through Kingsport to the Rogersville bypass. Turn right (northwest) onto Tennessee Highway 66; follow Tennessee Highway 66 for 8.3 miles (13 km) to *Stop 3* at crest of Stone Mountain.

The field trip route from Bristol to Kingsport (U.S. Highway 11) generally cuts across strike of beds on the hanging wall of the Pulaski fault. Near Kingsport the route enters the Saltville thrust sheet and traverses the Sevier Shale (Ordovician) around the northeast end of the Bays Mountain synclinorium. It then generally follows the Sevier-Knox contact south to Rogersville. Near Rogersville the field trip route again cuts across strike and traverses the Stone Mountain horse block to *Stop 3* in foot wall rocks of the Saltville thrust.



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B. Plot of fold axes, poles to axial surfaces, and elongation direction of boudins in Martinsburg Formation at *Stop 2*. Fold axes (x's) indicate that F_2 folds are generally east-west and subhorizontal as reflected in the areas labeled F_2. Some axes plot outside of these areas and reflect later, open folds and warps associated with high angle faults. The poles to axial surfaces (dots) have an approximate spread in orientation of 70°. The poles lie along a near vertical plane, reflecting a near horizontal axis of rotation (X labeled P) that falls within the F_2 area. This horizontal orientation is interpreted to mean that during the F_2/Salem thrusting event, early-formed folds were rotated (perhaps during transport of this tectonic slice) by forces that developed other, later-formed folds. Boudin (b) formed in limestone beds of the Martinsburg Formation are evidence that the intermediate axis of the strain ellipse for the F_2/Salem thrusting event was oriented approximately east-west. A cluster of several bryozoan colonies (Figure 4-5) were found to have their long axes (PS) generally parallel to F_2 fold axes and boudin. These bryozoan specimens appear to be examples of one of the special cases discussed by Ramsey (1967, p. 220-221) in which the original short axis of the bryozoan colonies were perpendicular to bedding. Because the greatest tectonic extension coincided with this direction, the long axes of the deformed colonies is parallel to a fold axis.

C. Plot of fold axes and poles to axial surfaces measured in the Elbrook Formation and Rome Formation at *Stop 2*. Axes (x's) of F_2 folds, areas labeled F_2, from the hanging wall of the Salem thrust reflect an east-west, subhorizontal trend as also shown in Figure 4-4B. Moreover, the geometric center (x labeled P2) of the concentration of poles to these axial surfaces shows an average axial surface (labeled F_2, AS) dipping steeply southeast and striking approximately N65°E. F_1 axes (x's in area labeled F_1) form a cluster of points which represent a shallow, southwesterly plunge. Poles to the F_1 axial surfaces fall along a surface with a steep, northeasterly dip (labeled F_1P) and with an axis of rotation (X labeled P) that falls within the cluster of points representing F_2 axes. This correspondence is evidence that F_1 axial surfaces are folded about F_2 axes and that at this locality F_2 and F_1 axes are almost coaxial. These relationships are illustrated in Figure 4-6.

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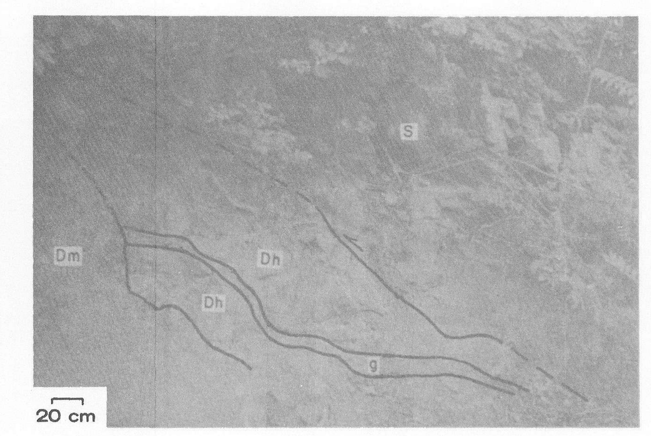

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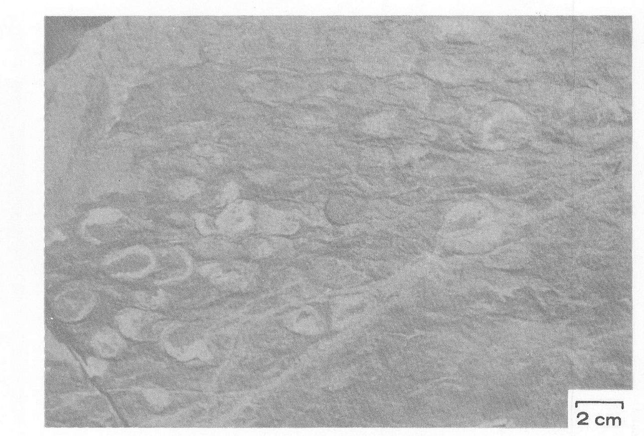

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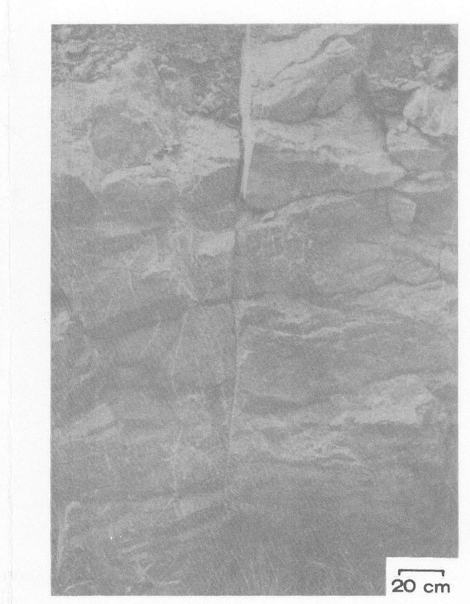

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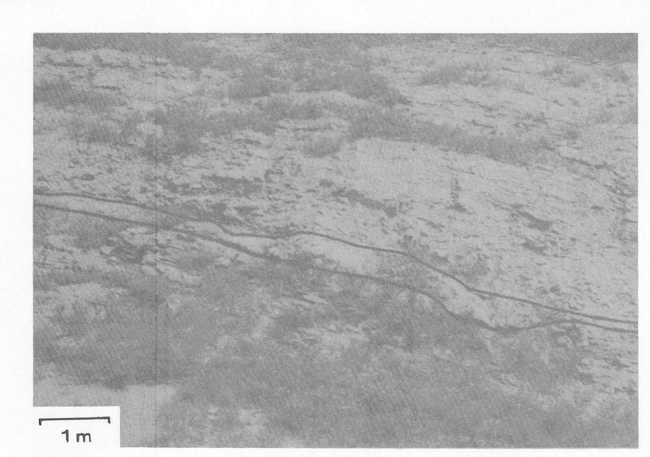

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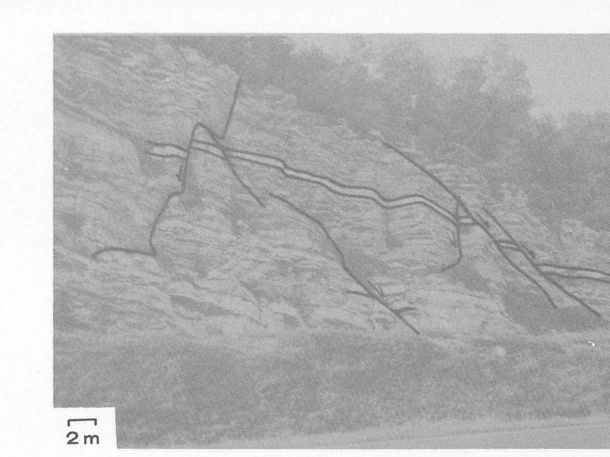

FIGURE 4-11 High angle faults in overturned, southeast dipping section of limestone and dolomite in the middle to lower part of the Elbrook Formation at I-81 mile 120.5.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

Part A. REGIONAL STRUCTURE AND HYDROCARBON POTENTIAL

By M. J. Bartholomew, Robert C. Milici, and A. P. Schultz

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 23
1980

GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 1 (of 6)

GEOLOGIC STRUCTURE ALONG THE SALTVILLE AND PULASKI FAULTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE

INTRODUCTION

This publication was prepared as the field guide for field trip 6, a pre-meeting trip run in conjunction with the 1980 Annual Meeting of the Geological Society of America, held in Atlanta, Georgia. Figure 1-1 shows the location of field trip stops (and alternates) to be visited in the Valley and Ridge and Cumberland Plateau of Virginia and Tennessee. Three stops, numbers one, two, and three, are described herein; descriptions of the other stops, including an alternate one shown on Figure 1-1, as well as geologic syntheses of Appalachian structure, are presented in Harris and Milici (1977), Milici (1978), and Butler and Hatcher (1979). Blue Ridge and Piedmont stops are described in Butler and Hatcher (1979). The locations of field trip stops 1 and 2, and oil and gas tests of major gas fields are shown in Figure 2-1.

The Saltville and Pulaski faults, located in the Eastern Low Angle Thrust Structural Province, are the two most extensive faults of the central and southern Appalachian Valley and Ridge (Milici, 1980). The Pulaski thrust extends from northern Virginia into eastern Tennessee, where it is overridden by the Meadow Creek fault along the toe of the Blue Ridge, and is the only major Valley and Ridge fault that extends from the central into the southern Appalachians. The Saltville fault extends from the Sinking Creek anticline in Virginia to the southwest through Tennessee into northwestern Georgia, where it merges with the Rome fault. The Saltville and the Pulaski faults place hanging wall strata, generally of Cambrian age, over footwall strata which are as young as Mississippian (see Harris and Milici, 1977, for summary of stratigraphy in field trip area).

The area described herein, a part of the "Eastern (or Appalachian) Overthrust belt" of petroleum geologists, is of particular interest because of the recent exploration for natural gas by major oil companies, the drilling of a Department of Energy natural gas test in Tennessee, the recent development of a well in the Early Grove gas field, and because of the major hydrocarbon discoveries in similar structures in the "Western Overthrust belt" in the Rockies.

THE GENERAL STRUCTURAL MODEL

STRUCTURAL FEATURES RELATED TO DECOLLEMENTS

A general model for Appalachian Valley and Ridge and Plateau structures was presented by Harris and Milici (1977). In this model thrust blocks above a decollement consist of a broken formation overlain by a zone of fracture. The broken formation, a tectonic breccia, is commonly cut by a variety of contractional and extensional faults. The overlying zone of fracture is composed of generally well-bedded strata which also are faulted and folded, but to a lesser extent than in the broken formation. The broken formation zone may be confined between beds of claystone, shale, coal, salt, anhydrite or other impervious beds; i.e., the zone is commonly bounded by well-defined, structurally weak beds which may act as seals for high pressure fluids. The nature of deformation associated with decollements may be best viewed near Dunlap, Tennessee, where deformed strata are continuously exposed for a mile along the Cumberland Plateau overthrust (Figure 1-2, from Harris and Milici, 1977).

Regional geologic maps of the Appalachians show that on hanging walls progressively younger Cambrian beds (Rome to Knox) are brought to the surface along thrust traces from west to east (Milici, 1980). Both this mapped distribution of formations along the traces of major thrusts and seismic profiles (Harris, 1976) show that position of decollement migrates upward from west to east across the Valley and Ridge province. In this process a broken formation formed from Cambrian rocks is progressively thickened and abandoned at depth from west to east (Figure 1-3). The eastwardly upmigration of the subhorizontal decollement levels is ultimately reversed and, near the Blue Ridge, the decollement at the base of the Paleozoic sequence descends beneath the broken formation into Precambrian sedimentary strata and crystalline rocks; these rocks are thrust westward over earlier formed folds and thrusts of the western Valley and Ridge province (Milici, 1975). The descent of thrusts beneath decollement at the level of the Lower Cambrian beds marks a major structural front similar in significance to the Plateau/Valley and Ridge front. In southwestern Virginia and northeastern Tennessee, the Pulaski fault marks this front.

Appalachian thrust sheets can be divided into three broad groupings which are related to their place of origin along the thrust zone; those formed at the upper decollement level; those formed along ramps; and those formed at the lower decollement level.

Upper decollement thrusts are extensively developed in the Appalachian Plateau; examples include the Cumberland Plateau overthrust, the western part of the Pine Mountain block, and extensive decollements in Ordovician and Silurian strata in the central Appalachian Plateau (Milici, 1980).

In some places ramp-derived structures, such as the Powell Valley anticline on the Pine Mountain block, are continuous with those of upper level thrust sheets. In other places the ramp-derived structures consist of bits and pieces of horse blocks caught between hanging and foot walls of major thrust sheets. Ramp-derived horse blocks are generally composed of steeply dipping strata which were cross-cut by thrusts as they ascended from lower to upper decollement levels. The horses almost always are oriented with the youngest beds facing the direction of tectonic transport (northwest), and are generally elongated in the direction of regional strike. Bedding in these horse blocks are usually steeply dipping to vertical or overturned.

A ramp-derived horse block, approximately two and one-half miles (4 km) wide and eleven miles (17.6 km) long, lies between the hanging and foot walls of the Saltville thrust near Rogersville, Tennessee (Figure 5-1). The horse block will be crossed en route to Stop 3. The horse contains beds which range in age from Cambrian to Mississippian and successively younger beds lie to the northwest. Orientation of beds in the horse range from nearly vertical to greatly overturned on the northwest limb of the structure, where beds of the Clinch (Silurian) and Chattanooga (Devonian-Mississippian) formations are thrust over beds in the footwall belonging to the Grainger (Mississippian) Formation.

Lower decollement-derived thrust sheets are bounded by the major eastward-dipping thrust faults. In each thrust sheet, hanging wall beds become younger to the east until the sequence is interrupted by the next succeeding thrust. Both surface mapping and recently obtained Vibroseis data show that the westernmost part of the Valley and Ridge consists of steeply inclined, imbricate thrust sheets, whereas the footwalls of the Saltville thrust and thrusts to the east of it appear to extend a substantial distance beneath the central and eastern part of the Valley and Ridge in northeastern Tennessee and southwestern Virginia (Milici, Harris and Statler, 1979).

Large folds in the central and southern Appalachians generally are formed in one or two ways: (1) as primary features related to the break thrusts or (2) as secondary features related to the shear thrusts of Willis (1893) (Milici, 1970). Primary folds form before and during the initial stages of break thrusting. The limbs of such folds are broken by movement on faults which pass through fold cores. Secondary or passive folds develop in the hanging wall as a result of a thrust sheet moving up a ramp to a structurally higher decollement level. Examples of large passive folds are the Middlesboro syncline and Powell Valley anticline of the Pine Mountain fault block (Harris, 1970). The Middlesboro syncline is developed above upper level decollement in the Chattanooga Shale, whereas the Powell Valley anticline formed where ramp-derived beds moved westward onto the subhorizontal upper level decollement.

Primary folds are recognized where folded footwalls are overridden by linear (undeformed) thrust traces. The St. Clair, Narrows and Saltville thrusts are break thrusts associated with primary folds (Figure 1-4). These faults terminate at the Roanoke orocline bend.

In contrast, the Pulaski, Blue Ridge and Rockfish Valley-Fries faults all trend around the Roanoke oroclinal bend into the central Appalachians (Figure 1-4). The Rockfish Valley-Fries fault represents a pre-Alleghanian ductile deformation zone, which is presumably cut off at depth by the Blue Ridge thrust. The Blue Ridge thrust and the complex Pulaski thrust were formed during Alleghanian deformation, and the Blue Ridge thrust appears to be younger than the Pulaski thrust.

STRUCTURAL EVOLUTION

Models proposing west to east (Milici, 1975) or east to west (Perry, 1978) imbrication of Appalachian thrust sheets have been proposed. In these models thrust faults develop from either the structurally lowest to the structurally highest zones (west to east model) or from the highest to the lowest zone (east to west model). From the Saltville fault northwestward across the western Valley and Ridge and Plateau provinces, most of the faults developed in a west to east manner, in keeping with a structurally lowest-to-highest model of evolution (Milici, 1975). The evidence which supports this interpretation is:

(1) fault-intersection relationships documented by Milici, (1975) in conjunction with

(2) seismic evidence that the thrusts do not converge at depth into a single decollement but remain as distinct, subparallel horizons (Harris, 1976), and

(3) the repetition of the stratigraphic sequences in each thrust sheet.

The relative ages of the Pulaski and Saltville thrusts are uncertain because of the absence of cross cutting relationships. Some structures on the Saltville block, however, are overridden by the Pulaski sheet and are therefore older than the Pulaski fault.

Evolution of the Pulaski and Blue Ridge thrust fault systems appears to be complex. Although the Blue Ridge fault is more easterly than the Saltville fault, it is clearly a structurally lower thrust because its hanging wall contains Lower Cambrian to Grenville age rocks. These older rocks are metamorphosed and occur substantially below the Cambrian-level decollement zone along which the more westerly faults moved. Similarly, detailed mapping in the Roanoke to Pulaski region has shown that the Pulaski thrust sheet was folded and broken by deeper structures after its emplacement. These structures resulted in exposures of rocks of the Saltville block in the Reed-Coyner Mountain, East Radford, Ingles-Barringer Mountain and Christiansburg windows, which are all para-allochthonous.

The Pulaski sheet and rocks exposed in its associated window have been deformed complexly. The thrust sheet consists of three major sub-blocks, the Salem synclinorium, the Fincastle syncline and the polydeformed terrane of the Pulaski fault system. Facies relationships in these blocks indicate about 30 to 35 miles (48 to 56 km) of displacement on faults of the Pulaski system (Bartholomew, 1979). Moreover, some folds in the Pulaski system appear to be related to movement of the Pulaski thrust sheet (the Salem synclinorium is an example), whereas others have resulted from later movement along thrusts at a lower level after the Pulaski sheet was emplaced (the Price Mountain anticline is an example). The Salem and Fincastle synclinoriums are separated from the polydeformed terrane of the Pulaski sheet by the Salem fault system which appears to be genetically related to the main Pulaski fault system (Figure 1-4).

Structures in the polydeformed terrane of the Pulaski-Salem fault system are the principal geologic features to be examined at the first two stops on this field trip. Bartholomew and Lowry (1979) were the first to recognize the polydeformed nature of this terrane and Schultz (1979a, 1979b) is currently studying several aspects of the structural evolution of the polydeformed terrane between Blacksburg and Pulaski (Figure 1-4). One of the primary features by which the polydeformed terrane is recognized is a set of folds, herein designated F_1, which predate syn-thrust Alleghanian folds (F_2) associated with emplacement of the Salem and Pulaski thrust sheets. The F_2 folds are found in both hanging walls and footwalls of the Salem and Pulaski fault systems. F_1 folds are confined to the polydeformed terrane of the hanging walls. Intimately associated with the folds of the polydeformed terrane are several types of breccia which first were recognized as "tectonic" in origin by Cooper (1939) and first described by Cooper and Haff (1940). In these papers the breccias were considered to be only fault breccias related to Alleghanian thrusting. We now recognize that the breccias probably had multiple origins related to both folding and faulting. Furthermore, the breccias are confined to a few rock types occurring in the uppermost Rome Formation and the lower portion of the Elbrook Formation. This more or less stratigraphic confinement of breccia (the question whether or not some of these are sedimentary breccias which have undergone tectonic deformation remains to be answered) led previous workers to infer that a fault (Max Meadow fault) separates the Elbrook and Rome formations in the polydeformed terrane. We now recognize both fault and stratigraphic contacts in the polydeformed terrane. In some places these contacts have breccias associated with them, and in others the breccias are absent.

In general, F_1 folds are subhorizontal isoclines which commonly have breccias in their cores. In many places the upper limbs of the F_1 folds are sheared off along the breccia core. Displacement in some cases is slight, whereas in others movement has occurred to the extent that the one limb and breccia are all that remain of the fold. Transposition of F_1 folds can be documented in thin sections of rocks in the polydeformed terrane.

On a regional scale the "Max Meadows line" serves to delimit the polydeformed terrane containing only the Rome Formation from that area containing intimately folded and faulted Rome and Elbrook formations and associated breccias (Figure 1-4).

Bartholomew (1979) postulated two possible modes of origin of the F_1 folds and the breccias of the polydeformed terrane on the Pulaski fault block. These are:

(1) the F_1 folds formed in a decollement zone during a pre-Alleghanian deformation (Taconic or Acadian) or,

(2) they formed in an early Alleghanian decollement zone and were subsequently exhumed by structurally lower thrusts (Figure 1-3). Because the F_1 folds are oriented at nearly right angles to the Alleghanian trend, it is inferred that either the folds were formed in an east-west stress system or that a very large area of the polydeformed terrane was rotated approximately 90° during thrusting. We believe that the hypothesis that the F_1 folds formed in response to a pre-Alleghanian deformation is more tenable.

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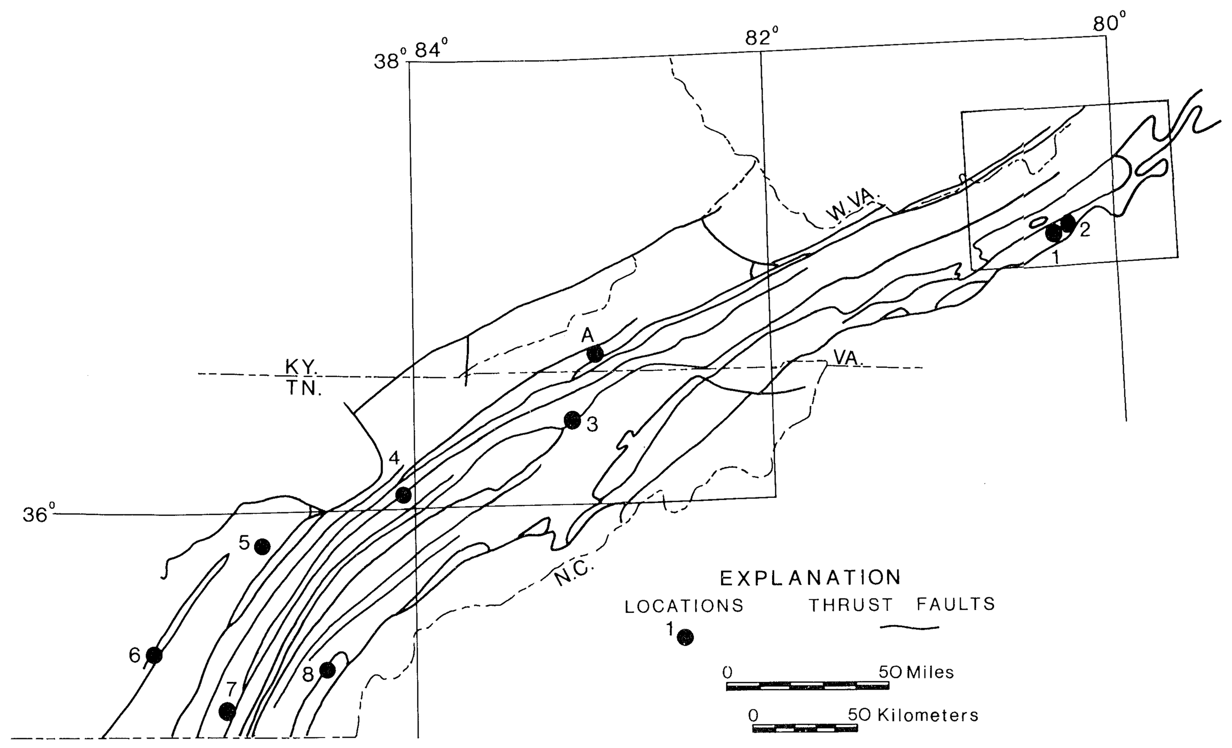


FIGURE 1-1. Location of field trip stops in the Valley and Ridge and Plateau provinces of Virginia and Tennessee. *Stops 1, 2,* and *3* are described in this report; the other stops designated on the figure are described in earlier reports (see text). Rectangle designates area of Figure 1-4.

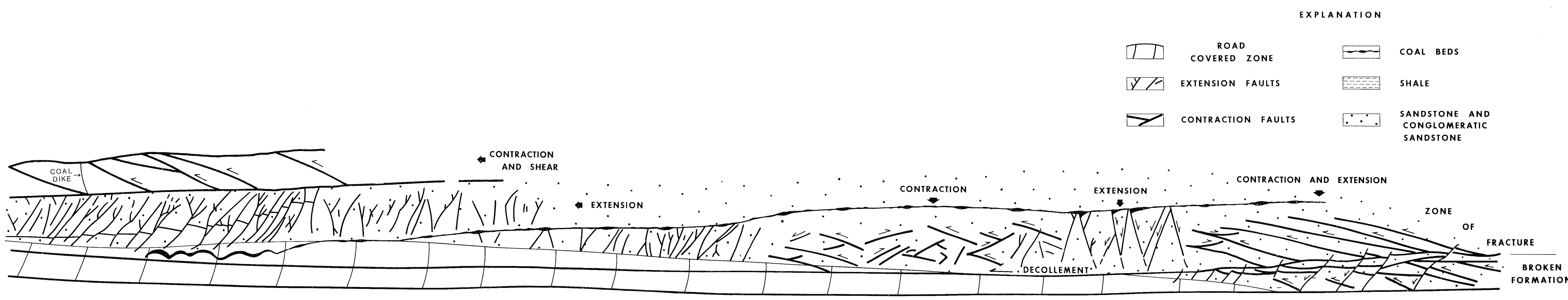


FIGURE 1-2. Interpretative diagram of the geologic structure in the Cumberland Plateau overthrust at Dunlap, Tennessee showing decollements and extensional and contractional faults (from Harris and Milici, 1977, Plate 3). Total horizontal distance represented is about 1 mile; maximum vertical dimension is 50 feet.

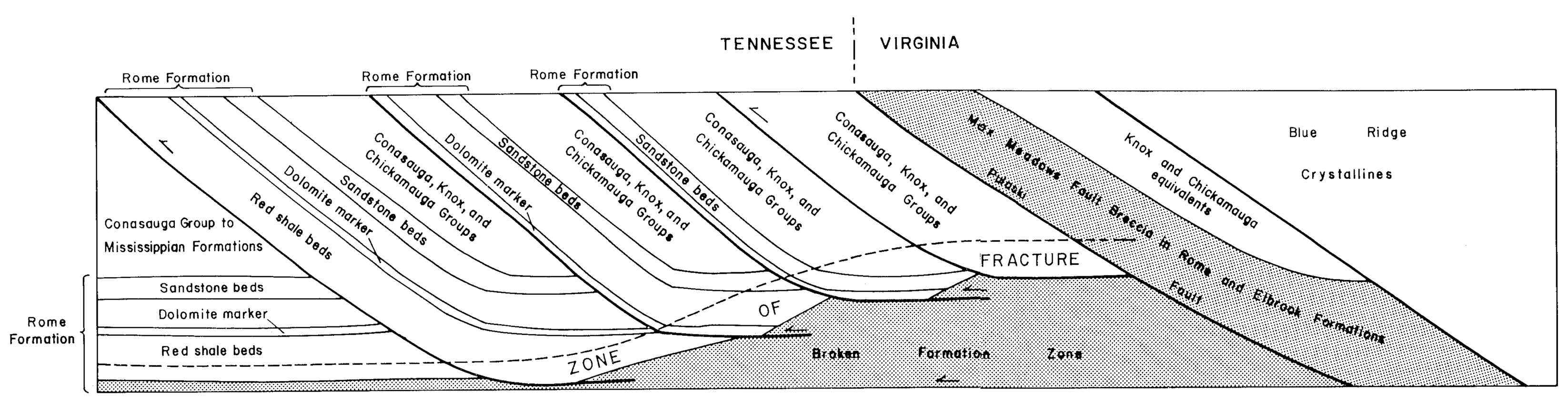
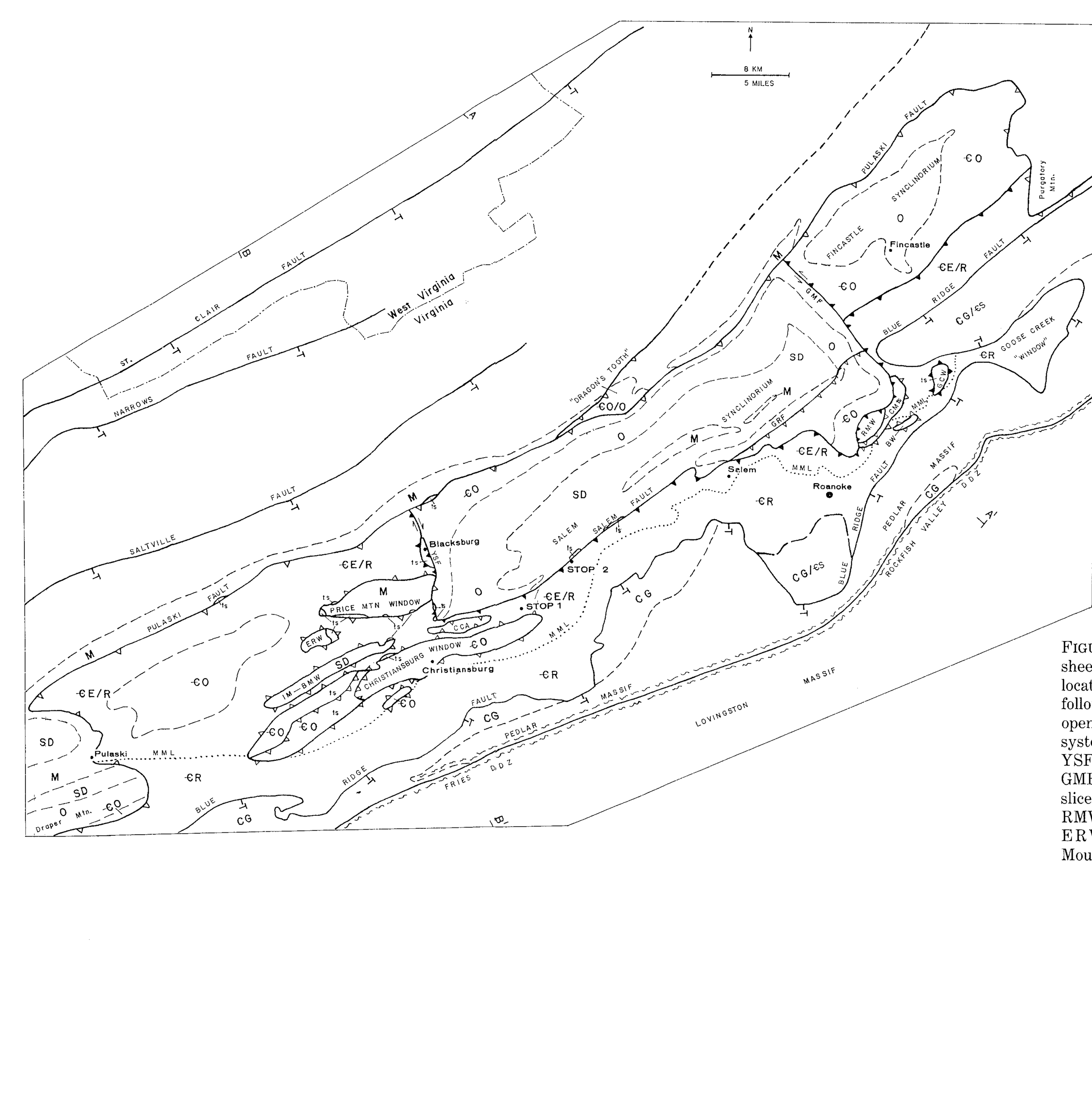


FIGURE 1-3. Diagram of structural levels of decollement in the Southern Appalachians.



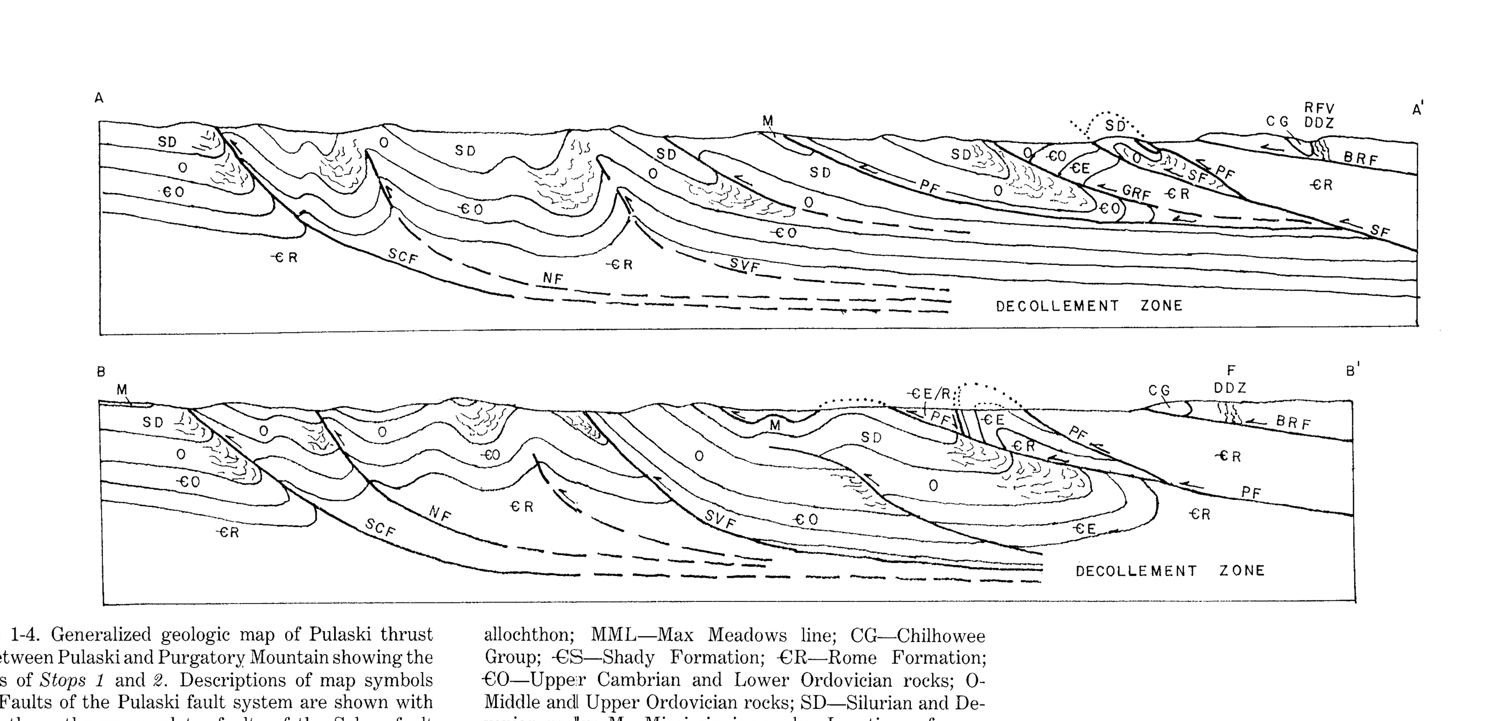


FIGURE 1-4. Generalized geologic map of Pulaski thrust sheet between Pulaski and Purgatory Mountain showing the locations of *Stops 1* and *2*. Descriptions of map symbols follow. Faults of the Pulaski fault system are shown with open teeth on the upper plate; faults of the Salem fault system are shown with solid teeth on the upper plate; YSF—Yellow Sulfur fault; GRF—Green Ridge fault; GMF—Glebe Mills fault; CMTS—Coyner Mountain tectonic slice; ts—tectonic slice; GCW—Glade Creek window; RMW—Reed Mountain window; BW—Bonsack window; ERW—East Radford window; IM-BMW—Ingles Mountain-Berringer Mountain window; CCA—Crab Creek allochthon; MML—Max Meadows line; CG—Chilhowee Group; ЄS—Shady Formation; ЄR—Rome Formation; ЄO—Upper Cambrian and Lower Ordovician rocks; O-Middle and Upper Ordovician rocks; SD—Silurian and Devonian rocks; M—Mississippian rocks. Locations of cross sections A-A′ and B-B′ are shown on map; the sections have no vertical exaggeration. Rock symbols for sections are the same as on map. Other symbols are: PF—Pulaski fault; SF—Salem fault; BRF—Blue Ridge fault; SVF—Saltville fault; NF—Narrows fault; SCF—Saint Clair fault; RFVDDZ—Rockfish Valley fault & ductile deformation zone; FDDZ—Fries fault & ductile deformation zone.

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

Part A. REGIONAL STRUCTURE AND HYDROCARBON POTENTIAL

By M. J. Bartholomew, Robert C. Milici, and A. P. Schultz

GEOLOGIC STRUCTURE ALONG THE SALTVILLE AND PULASKI FAULTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE

INTRODUCTION

This publication was prepared as the field guide for field trip 6, a pre-meeting trip run in conjunction with the 1980 Annual Meeting of the Geological Society of America, held in Atlanta, Georgia. Figure 1-1 shows the location of field trip stops (and alternates) to be visited in the Valley and Ridge and Cumberland Plateau of Virginia and Tennessee. Three stops, numbers one, two, and three, are described herein; descriptions of the other stops, including an alternate one shown on Figure 1-1, as well as geologic syntheses of Appalachian structure, are presented in Harris and Milici (1977), Milici (1978), and Butler and Hatcher (1979). Blue Ridge and Piedmont stops are described in Butler and Hatcher (1979). The locations of field trip stops 1 and 2, and oil and gas tests of major gas fields are shown in Figure 2-1.

The Saltville and Pulaski faults, located in the Eastern Low Angle Thrust Structural Province, are the two most extensive faults of the central and southern Appalachian Valley and Ridge (Milici, 1980). The Pulaski thrust extends from northern Virginia into eastern Tennessee, where it is overridden by the Meadow Creek fault along the toe of the Blue Ridge, and is the only major Valley and Ridge fault that extends from the central into the southern Appalachians. The Saltville fault extends from the Sinking Creek anticline in Virginia to the southwest through Tennessee into northwestern Georgia, where it merges with the Rome fault. The Saltville and the Pulaski faults place hanging wall strata, generally of Cambrian age, over footwall strata which are as young as Mississippian (see Harris and Milici, 1977, for summary of stratigraphy in field trip area).

The area described herein, a part of the "Eastern (or Appalachian) Overthrust belt" of petroleum geologists, is of particular interest because of the recent exploration for natural gas by major oil companies, the drilling of a Department of Energy natural gas test in Tennessee, the recent development of a well in the Early Grove gas field, and because of the major hydrocarbon discoveries in similar structures in the "Western Overthrust belt" in the Rockies.

THE GENERAL STRUCTURAL MODEL

Structural Features Related to Decollements

A general model for Appalachian Valley and Ridge and Plateau structures was presented by Harris and Milici (1977). In this model thrust blocks above a decollement consist of a broken formation overlain by a zone of fracture. The broken formation, a tectonic breccia, is commonly cut by a variety of contractional and extensional faults. The overlying zone of fracture is composed of generally well-bedded strata which also are faulted and folded, but to a lesser extent than in the broken formation. The broken formation zone may be confined between beds of claystone, shale, coal, salt, anhydrite or other impervious beds; i.e., the zone is commonly bounded by well-defined, structurally weak beds which may act as seals for high pressure fluids. The nature of deformation associated with decollements may be best viewed near Dunlap, Tennessee, where deformed strata are continuously exposed for a mile along the Cumberland Plateau overthrust (Figure 1-2, from Harris and Milici, 1977).

Regional geologic maps of the Appalachians show that on hanging walls progressively younger Cambrian beds (Rome to Knox) are brought to the surface along thrust traces from west to east (Milici, 1980). Both this mapped distribution of formations along the traces of major thrusts and seismic profiles (Harris, 1976) show that position of decollement migrates upward from west to east across the Valley and Ridge province. In this process a broken formation formed from Cambrian rocks is progressively thickened and abandoned at depth from west to east (Figure 1-3). The eastwardly upmigration of the subhorizontal decollement levels is ultimately reversed and, near the Blue Ridge, the decollement at the base of the Paleozoic sequence descends beneath the broken formation into Precambrian sedimentary strata and crystalline rocks; these rocks are thrust westward over earlier formed folds and thrusts of the western Valley and Ridge province (Milici, 1975). The descent of thrusts beneath decollement at the level of the Lower Cambrian beds marks a major structural front similar in significance to the Plateau/Valley and Ridge front. In southwestern Virginia and northeastern Tennessee, the Pulaski fault marks this front.

Appalachian thrust sheets can be divided into three broad groupings which are related to their place of origin along the thrust zone; those formed at the upper decollement level; those formed along ramps; and those formed at the lower decollement level.

Upper decollement thrusts are extensively developed in the Appalachian Plateau; examples include the Cumberland Plateau overthrust, the western part of the Pine Mountain block, and extensive decollements in Ordovician and Silurian strata in the central Appalachian Plateau (Milici, 1980).

In some places ramp-derived structures, such as the Powell Valley anticline on the Pine Mountain block, are continuous with those of upper level thrust sheets. In other places the ramp-derived structures consist of bits and pieces of horse blocks caught between hanging and foot walls of major thrust sheets. Ramp-derived horse blocks are generally composed of steeply dipping strata which were cross-cut by thrusts as they ascended from lower to upper decollement levels. The horses almost always are oriented with the youngest beds facing the direction of tectonic transport (northwest), and are generally elongated in the direction of regional strike. Bedding in these horse blocks are usually steeply dipping to vertical or overturned.

A ramp-derived horse block, approximately two and one-half miles (4 km) wide and eleven miles (17.6 km) long, lies between the hanging and foot walls of the Saltville thrust near Rogersville, Tennessee (Figure 5-1). The horse block will be crossed en route to Stop 3. The horse contains beds which range in age from Cambrian to Mississippian and successively younger beds lie to the northwest. Orientation of beds in the horse range from nearly vertical to greatly overturned on the northwest limb of the structure, where beds of the Clinch (Silurian) and Chattanooga (Devonian-Mississippian) formations are thrust over beds in the footwall belonging to the Grainger (Mississippian) Formation.

Lower decollement-derived thrust sheets are bounded by the major eastward-dipping thrust faults. In each thrust sheet, hanging wall beds become younger to the east until the sequence is interrupted by the next succeeding thrust. Both surface mapping and recently obtained Vibroseis data show that the westernmost part of the Valley and Ridge consists of steeply inclined, imbricate thrust sheets, whereas the footwalls of the Saltville thrust and thrusts to the east of it appear to extend a substantial distance beneath the central and eastern part of the Valley and Ridge in northeastern Tennessee and southwestern Virginia (Milici, Harris and Statler, 1979).

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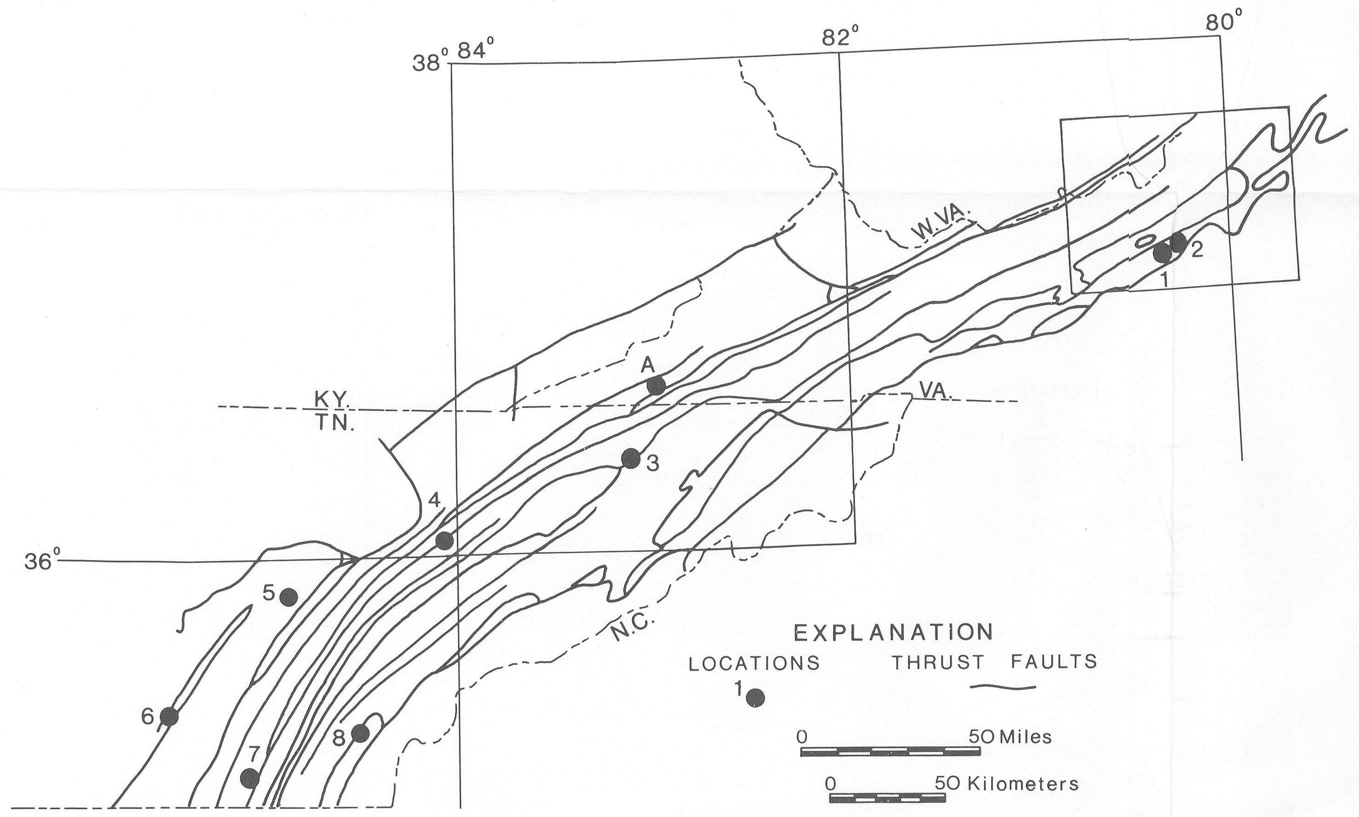


FIGURE 1-1. Location of field trip stops in the Valley and Ridge and Plateau provinces of Virginia and Tennessee. *Stops 1, 2,* and *3* are described in this report; the other stops designated on the figure are described in earlier reports (see text). Rectangle designates area of Figure 1-4.

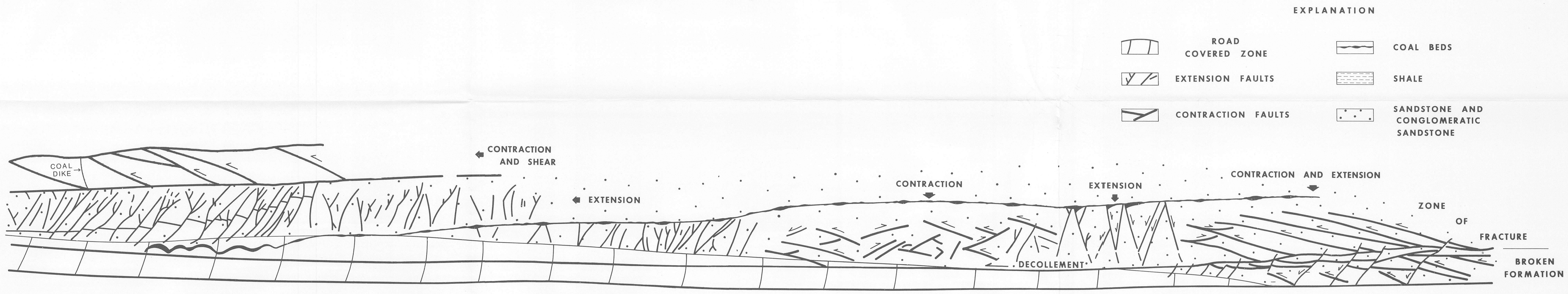


FIGURE 1-2. Interpretative diagram of the geologic structure in the Cumberland Plateau overthrust at Dunlap, Tennessee showing decollements and extensional and contractional faults (from Harris and Milici, 1977, Plate 3). Total horizontal distance represented is about 1 mile; maximum vertical dimension is 50 feet.

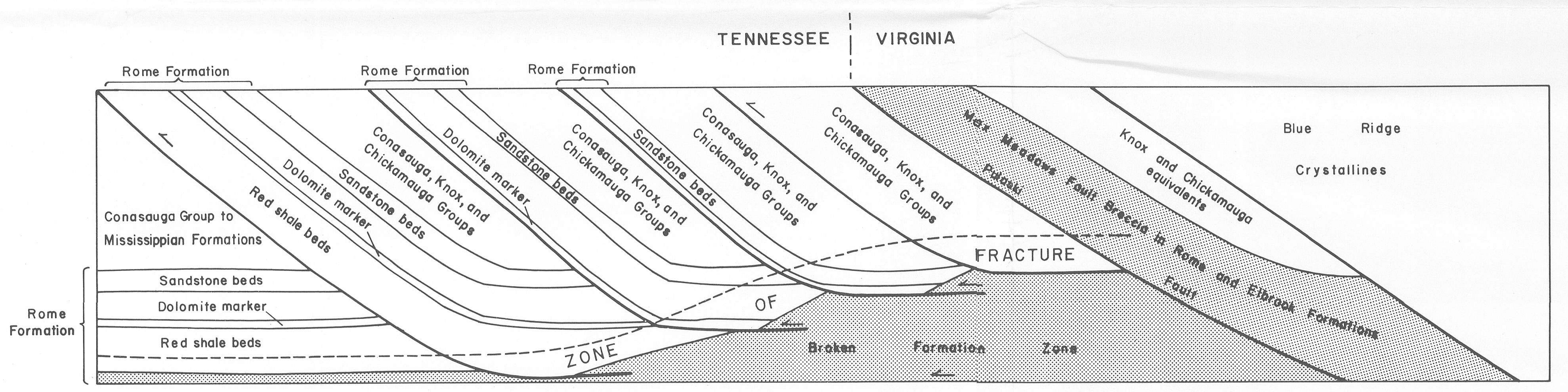
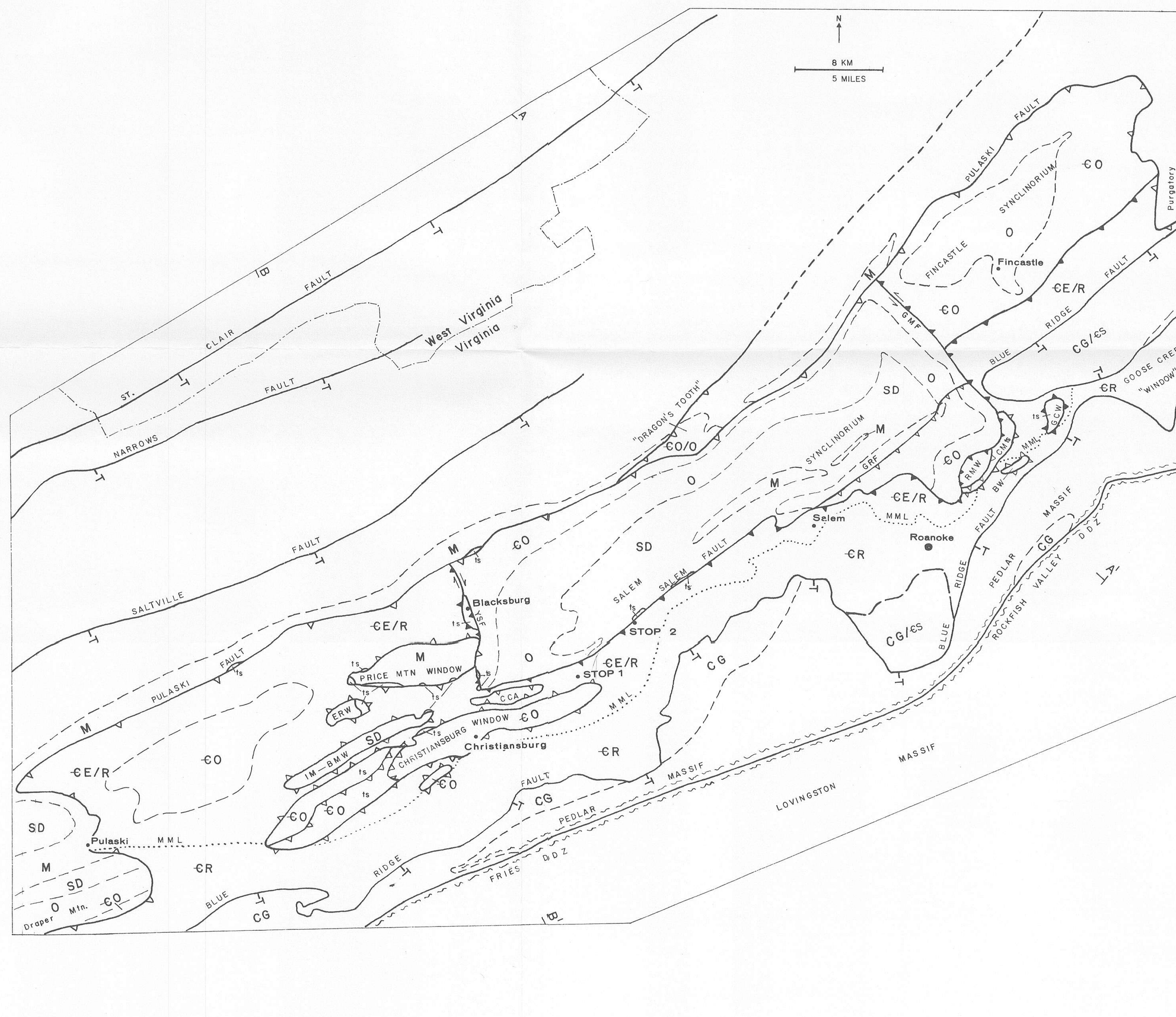


FIGURE 1-3. Diagram of structural levels of decollement in the Southern Appalachians.



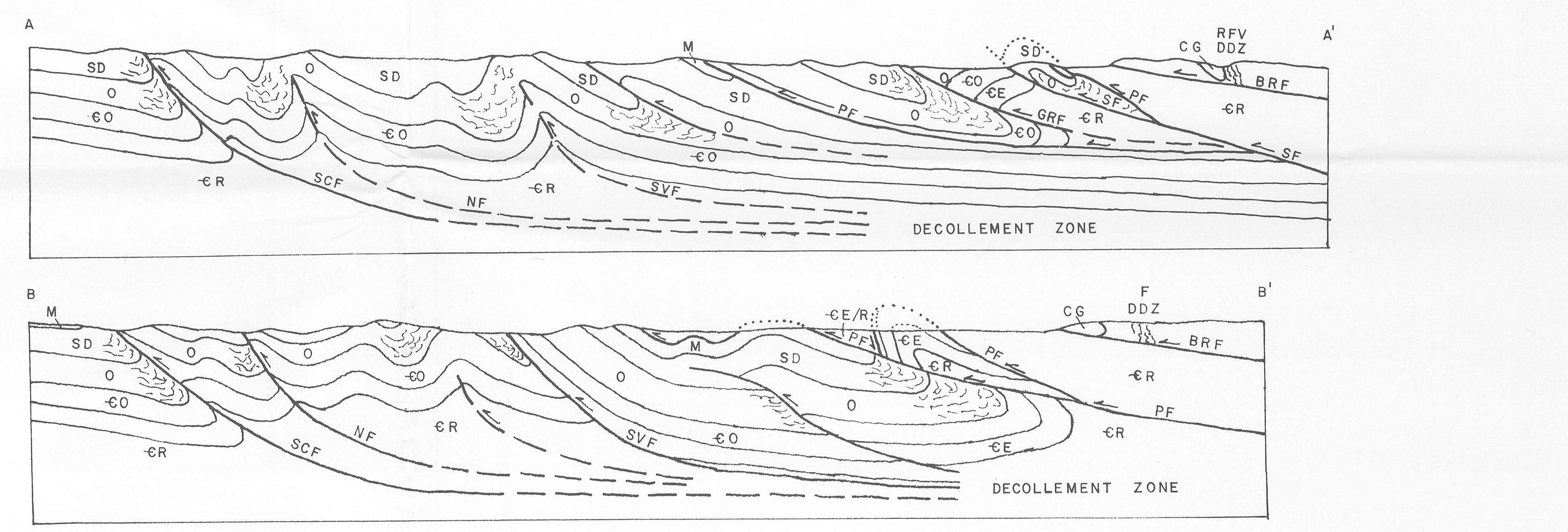


FIGURE 1-4. Generalized geologic map of Pulaski thrust sheet between Pulaski and Purgatory Mountain showing the locations of *Stops 1* and *2*. Descriptions of map symbols follow. Faults of the Pulaski fault system are shown with open teeth on the upper plate; faults of the Salem fault system are shown with solid teeth on the upper plate; YSF—Yellow Sulfur fault; GRF—Green Ridge fault; GMF—Glebe Mills fault; CMTS—Coyner Mountain tectonic slice; ts—tectonic slice; GCW—Glade Creek window; RMW—Reed Mountain window; BW—Bonsack window; ERW—East Radford window; IM-BMW—Ingles Mountain-Berringer Mountain window; CCA—Crab Creek allochthon; MML—Max Meadows line; CG—Chilhowee Group; ЄS—Shady Formation; ЄR—Rome Formation; ЄO—Upper Cambrian and Lower Ordovician rocks; O-Middle and Upper Ordovician rocks; SD—Silurian and Devonian rocks; M—Mississippian rocks. Locations of cross sections A-A′ and B-B′ are shown on map; the sections have no vertical exaggeration. Rock symbols for sections are the same as on map. Other symbols are: PF—Pulaski fault; SF—Salem fault; BRF—Blue Ridge fault; SVF—Saltville fault; NF—Narrows fault; SCF—Saint Clair fault; RFVDDZ—Rockfish Valley fault & ductile deformation zone; FDDZ—Fries fault & ductile deformation zone.

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DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

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GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 3 (of 6)

Part B. DEFORMATION IN THE HANGING WALL OF THE PULASKI THRUST SHEET NEAR IRONTO, MONTGOMERY COUNTY, VIRGINIA. STOP 1

By M. J. Bartholomew and A. P. Schultz

ROAD LOG

Interstate 81
Milepost
mileage

118.1 Group coming from Christiansburg on U.S. Highway 11 or from Blacksburg on U.S. Highway 460. Turn right onto the ramp for Interstate 81 north at Interchange 37.

119.0 Milepost marker, Knox dolomite exposed in cuts.

119.3 Leave the Christiansburg window (Figure 3-1) and enter the polydeformed terrane of the Pulaski thrust sheet. Our preliminary structural data, presented herein, indicate that the polydeformed terrane of the Pulaski sheet has a set of folds (F_1) older than those folds (F_2) formed during the Alleghanian deformation, the time of movement on the Salem and Pulaski faults. At *Stop 1* (sheet 3) plots of axes and poles to axial surfaces indicate that northwest-southeast plunging, commonly reclined, F_1 folds are refolded about northeast-southwest trending axes (F_2). At *Stop 2*, (sheet 4) Alleghanian deformation produced footwall strain features that reflect a single deformational event. Moreover, at *Stop 2*, as at *Stop 1*, the hanging wall strain features in the polydeformed terrane indicate a set of pre-existing folds (F_1) refolded about F_2. Regionally, the general orientation of F_1 features suggests that they formed in a stress field with a northeast-southwest direction of compression; this compressive direction was at nearly right angles to that (NW-SE compressive direction) which produced the Alleghanian strain features.

120.65 Outcrops of thin-bedded argillaceous dolomites with zones of breccia and also calcite veins and small-scale folds and faults.

121.85 *STOP 1.* (Note: permission must be obtained from the Virginia State Police before stopping along the Interstate.) Park at the northeast end of the outcrop at the top of the hill and walk back to the southwest along the top of the median strip. The exposures on the south and north sides of the Interstate are shown on Figures 3-2 and 3-3, respectively. The exposures on the south side of the median strip are shown on Figure 3-4 and will be examined in more detail after viewing the larger features. These road cuts reveal the nature of the complexly folded, faulted and brecciated Elbrook and Rome formations found north of the Max Meadows line (Figure 1-4). Note that the overall structure in Figure 3-2 is essentially a large westward-directed thrust overriding large reclined F_1 folds. F_1 axial surfaces generally trend northwest-southeast (Figure 3-5) and many fold hinges are broken by small faults. The main fault is apparently offset by a steeper fault (Figure 3-2). The large syncline at the "southwestern end" of Figure 3-2 is the structure at the "northeastern end" of Figure 3-3. The change in attitude of its axis and axial surface is shown in Figure 3-5. Breccias apparently have several modes of formation and/or emplacement. Neither the brecciated Rome Formation nor the highly fractured, massive dolomite appear to be very mobile and, except for clasts within the polymictic carbonate breccia, breccias are generally formed *in situ* closely associated with the parental rock types. However, the polymictic carbonate breccia was apparently quite mobile during deformation. We infer its mobility from small breccia-filled faults such as the one at the "southwestern end" of Figure 3-2 where a limestone unit is offset along a narrow zone of breccia containing dolomite clasts. Likewise, breccia commonly truncates many beds and folds without zones of visible disruption; clasts of adjacent host rocks are still recognizable in these breccias, but the clasts have been rotated. The most likely explanation for breccia mobility would be that it moved out of tightly compressed fold cores under high fluid pressure into any adjacent openings. Some breccias formed along thrust faults; these are, in most places, narrow and grade vertically into highly disrupted bedding that in turn grades into typical, thin-bedded dolomite. High angle faults such as the one offsetting the thrust in Figure 3-2 are visible on all scales and most easily observed where bedding is not disrupted greatly.

124.85 Excellent exposures of polymictic carbonate breccias and smaller zones of breccia derived from green phyllitic mudstones of the Rome Formation are on the right.

127.0 The area shown in Figure 4-2 is exposed along the south bound lane.

127.3 The Salem fault is exposed in this outcrop about 25 feet (8 m) above the road level. Here, dolomite of the Cambrian-age Elbrook Formation is in thrust contact with limestones and shale of the Ordovician-age Martinsburg Formation. The fault dips about 30° to the southeast. The Martinsburg Formation also is exposed below the thrust sheet in the stream flowing within the median strip.

127.9 Cross the Salem fault onto an underlying tectonic slice (Martinsburg Formation to north; Elbrook Formation to south).

128.05 Exit at Interchange 38 (Ironto exit) bear right and turn left to cross over Interstate 81.

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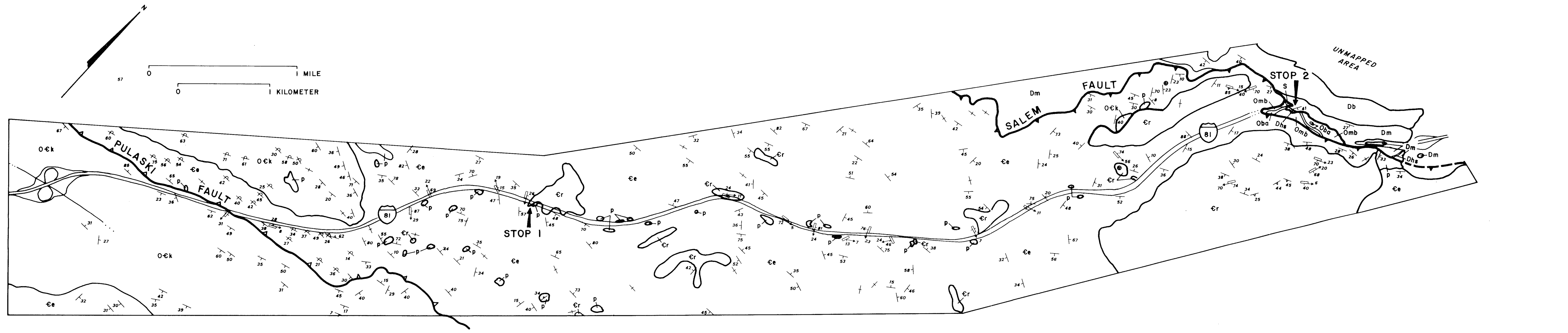

FIGURE 3-1. Geologic map along Interstate 81 between the Christiansburg and Ironto interchanges (numbers 37 and 38, respectively), showing locations of *Stops 1* and *2*. Geology in Ironto quadrangle modified from Broughton (1971); geology in the Elliston quadrangle and modifications of Broughton's work by M. J. Bartholomew and A. P. Schultz.

MAP EXPLANATION—ROCK UNITS

Db — *Brallier Fm.* Interbedded cyclic sequences of 10 cm-thick, dark-gray, medium-to fine-grained silty sandstone and dark-gray to black, fissile mudstone; fossiliferous in places.

Dm — *Millboro Fm.* Dark-gray to black sparsely fossiliferous, fissile, very thin bedded (0.1-1 cm) mudstone with minor amounts of 1-2 cm thick siltstone interbeds; manganese-bearing concretions occur locally. *Styliolina sp.* occurs in the Millboro at *Stop 2*.

Dhs — *Huntersville chert* and overlying sandstones—0.5-1-meter-thick, irregularly bedded black chert and coarse-to medium-grained, dark-grayish-green, glauconitic sandstone.

S — *Silurian cataclasite*—light-gray to white, medium- to coarse-grained (with some pebble lenses) quartz sandstone with a penetrative cataclastic fabric.

Omb — *Martinsburg Fm.* light- to medium-gray, thin-bedded (3-10 cm) fossilliferous limestone, interbedded with light- to dark-gray, calcareous mudstone. Limestones contain bondinage surrounded by intensely sheared and folded mudstones. Fossils include trilobites, brachiopods, crinoids and bryozoans.

Oba — *Bays Fm.* Greenish-gray to dark-gray, medium- to coarse-grained, non-fossiliferous, massive-bedded sandstone.

O-Ꞓk — *Knox Group* (undivided): Light- to medium-gray, massive to thick-bedded, fine- to medium-grained dolomite with quartzose sandstones and siliceous oolite interbeds in the lower portion and thick beds of massive chert and limestone in the upper portion.

Ꞓe — *Elbrook Fm.* Light-blue-gray, interbedded massive to thinly laminated, stylolitic limestones; gray to dark-gray, massive to thickly bedded dolomite and light-gray laminated (cm to mm) argillaceous dolomite.

Ꞓr — *Rome Fm.* Grayish-green, thin-bedded calcareous phyllitic mudstone with minor amounts of maroon phyllitic mudstone and thin dolomite interbeds. Brecciated in places.

p — *Polymictic carbonate breccia* Medium- to light-gray, unsorted and poorly indurated, crudely layered to massive polymictic carbonate breccia.

20 Strike and dip of beds

Strike and dip of vertical beds

Horizontal beds

85 Strike and dip of overturned beds

40 Strike and dip of cleavage

40 Strike and dip of compositional layering

28 Direction and angle of plunge of minor fold with vertical axial surface

22 69 Direction and angle of plunge of minor fold showing strike and dip of axial surface

70 Direction and angle of plunge of minor fold showing strike and dip of axial plane foliation (or cleavage)

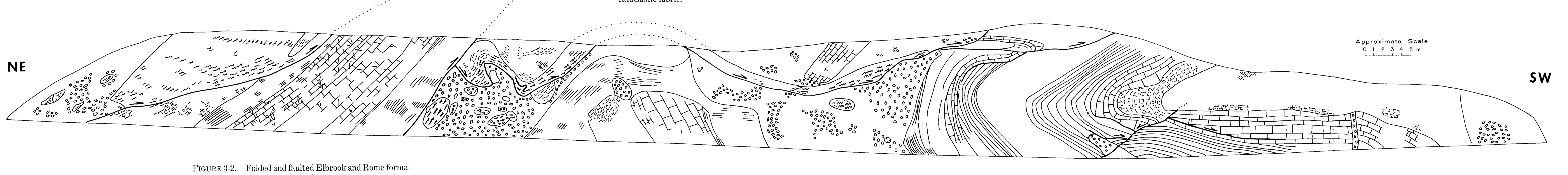

FIGURE 3-2. Folded and faulted Elbrook and Rome formations along south side of I-85 at *Stop 1*.

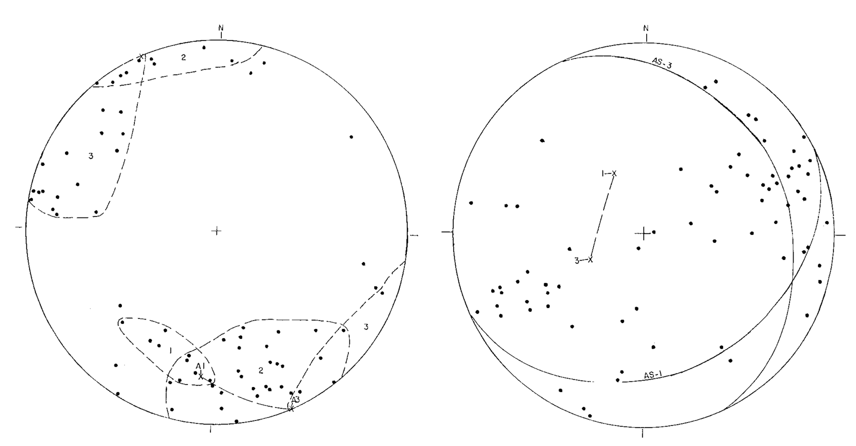

FIGURE 3-5. Lower hemisphere Schmidt net projections of structural data collected at *Stop 1*.

A. Plot of fold axes at *Stop 1*; areas labeled 1, 2, and 3 indicate concentrations of data collected from the south side, median strip, and north side of the Interstate, respectively. The change in the trend and plunge of the large syncline is indicated by x's labeled A1 (southside) and A3 (north side). The line of rotation from A1 to A3, as well as the spread of the data from areas 1, 2, and 3, indicate that most of earlier fold axes (F_1), such as the large syncline, were refolded about a NE-SW trending axis of rotation.

B. Plot of poles to axial surfaces of folds at *Stop 1*. The approximate axial surface of the large syncline is shown as AS-1 (south side) and AS-3 (north side) and the corresponding poles to the axial surfaces are labeled 1 and 3. The change in the position of the pole suggests refolding about an east-west axis; most of the axial surfaces are oriented in a NW-SE position, hence their poles are concentrated in a NE-SW direction. Because the axes of rotation of both stages of folding are oriented in a NE-SW direction, the pole plots reflect the refolding more so than do the axes (Figure 3-5A).

Rome Formation

a. b. Thin bedded (1-3 cm) calcareous grayish-green phyllitic mudstone (a) with minor maroon phyllitic mudstone and dolomite interbeds. Bedding in places is disrupted by intense folding and faulting; this rock grades into brecciated phyllitic mudstone, (b) which consists of grayish-green massive to crudely layered rock with grayish-green and maroon phyllitic mudstone fragments in a macerated poorly indurated matrix of smaller fragments with calcite and dolomite cement; some dolomite clasts are present.

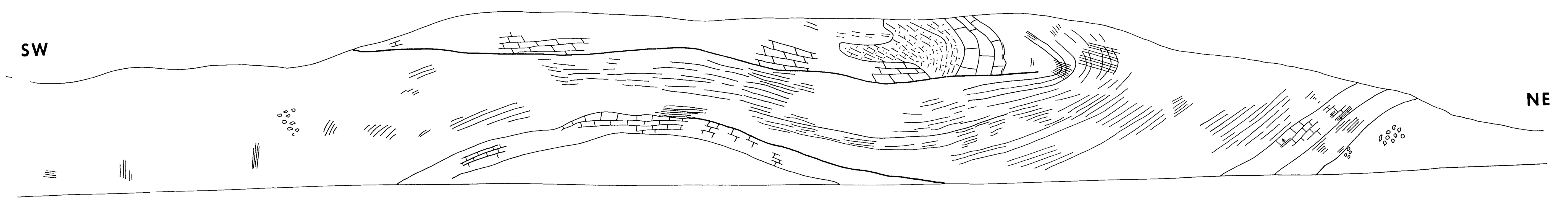

FIGURE 3-3. Folded and faulted Elbrook and Rome Formations along north side of I-85 at *Stop 1*.

Elbrook Formation

1. Limestone unit—massive to thinly laminated light-bluish-gray limestone, stylolitic with thin algal laminated beds, stromatolites and some minor dolomatized burrows. Calcite veins are abundant locally.
2. Massive dolomite (a) and highly fractured, massive dolomite (b). Massive to thickly bedded dolomite, fine- to coarse-grained, medium- to light-gray, with stylolitic seams defining beds up to 1 meter thick. Beds may be burrow mottled and in places algal laminated. When brecciated this rock becomes a massive, medium- to dark-gray highly fractured dolomite; the fractures are closely spaced and are generally perpendicular to bedding. This rock weathers to small rectangular fragments.
3. Thin bedded dolomite (a) and polymictic carbonate breccia (b), laminated (cm to mm), light to medium-gray dolomite with argillaceous greenish-gray partings. Cross bedded in places. A few beds show probable solution disruption with large vugs containing calcite and dolomite crystals. This classic "Max Meadows," polymictic carbonate breccia is medium- to light-gray, unsorted, poorly indurated, and crudely layered to massive. Clasts of dolomite are sub-rounded to angular, generally 1-10 cm in diameter, but diameters reach one meter. Larger blocks of well indurated carbonate breccia occur in the matrix. Matrix is a mixture of dolomite and greenish phyllitic mudstone surrounded by a dolomite "rock flour" that in places bears calcareous cement; includes fragments less than 1 cm.

En echelon calcite veins

Faults

Cleavage

Direction of younger beds

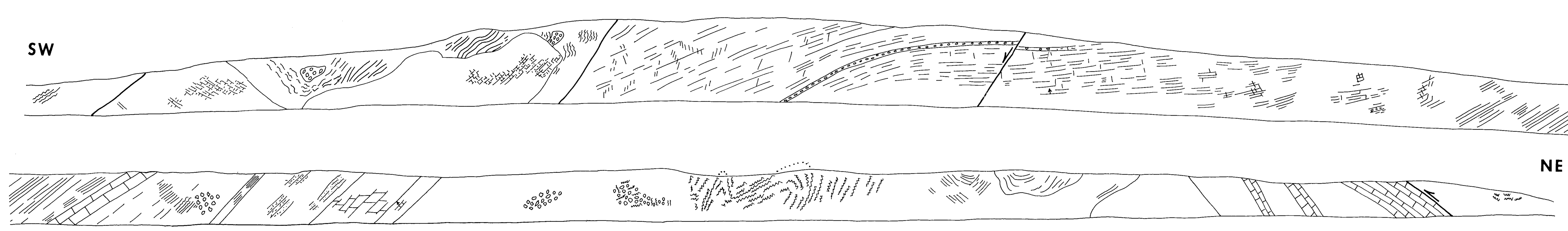

FIGURE 3-4. Folded and faulted Elbrook and Rome formations along south side of median strip of I-81 at *Stop 1*.

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Part C. SALTVILLE FAULT FOOTWALL STRUCTURE AT STONE MOUNTAIN, HAWKINS COUNTY, TENNESSEE STOPS 3B, C

By Robert C. Milici

VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 23
1980

GEOLOGIC STRUCTURE AND HYDROCARBON POTENTIAL ALONG THE SALTVILLE AND PULASKI THRUSTS IN SOUTHWESTERN VIRGINIA AND NORTHEASTERN TENNESSEE.
Sheet 6 (of 6)

STOP 3B—Walk downward along Tennessee Highway 66 through complexly folded and faulted siltstones and shales (not figured) to *STOP 3B*, Figure 6-1. Note that the road is constructed along and across the direction of tectonic transport. Beds exposed at *Stop 3B* belong to member c of the Grainger; the beds, which contain glauconite, are extensionally faulted. An extensional fault near the top of the cut appears to be listric normal, i.e., the fault is normal at its head but has a thrust component at its subhorizontal toe. A coarsening-upward sequence near the bottom of the cut suggests that the strata here are right-side up.

STOP 3C—Walk downward along roadway to *Stop 3C* (Figure 6-2). The major structure is a westwardly inclined low angle thrust, along which extensionally faulted beds of unit b are both in the footwall and in the hanging wall. Carbonaceous shales along the fault may be Chattanooga Shale. Minor folds are evidence that most beds are right-side up. Because these extensional faults do not cross the low angle thrust, it is inferred that each set is related to movement along underlying thrusts. From the structural truncations it is evident that episodes of faulting and folding advanced progressively upward during deformation.

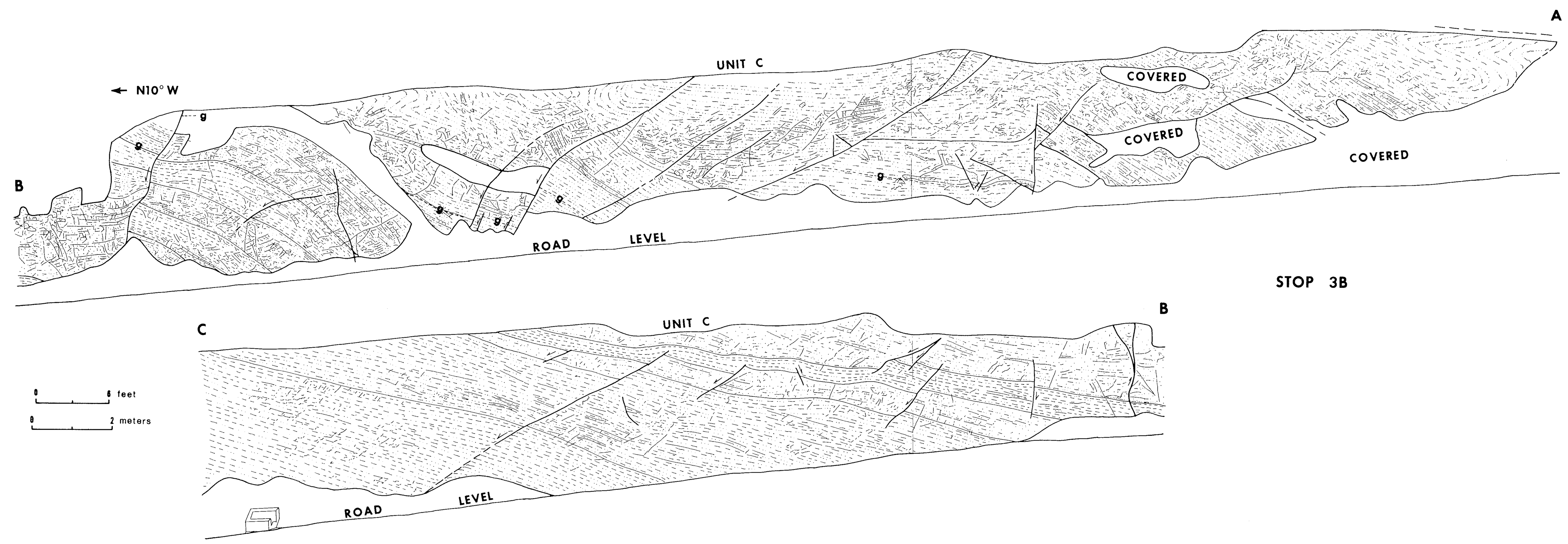
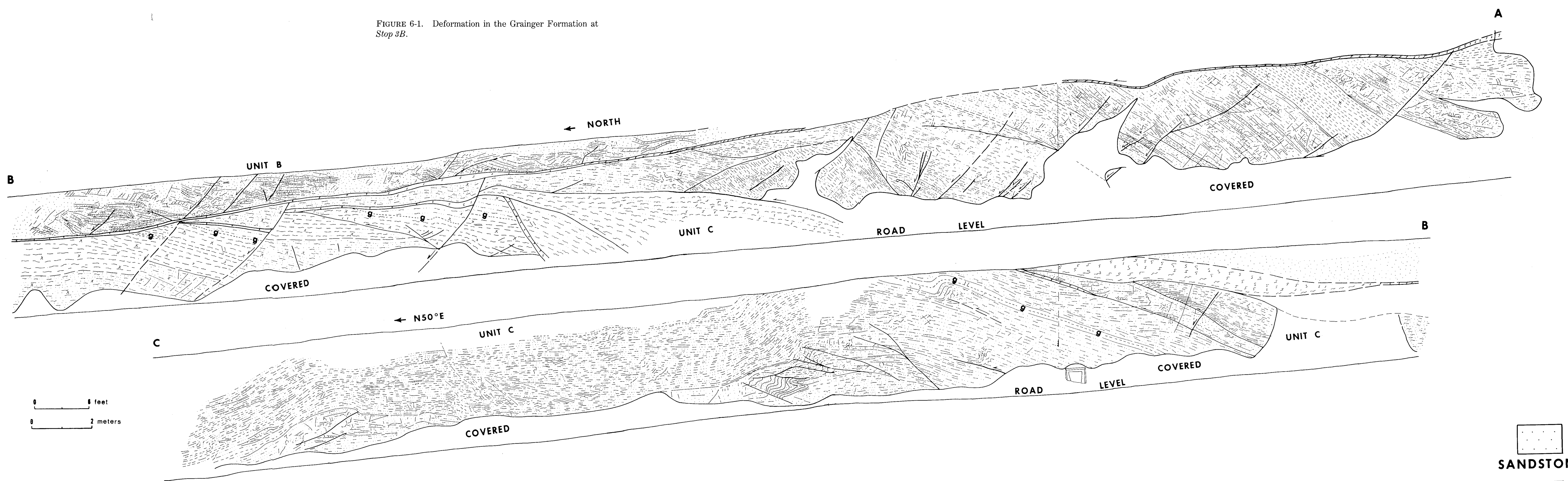


FIGURE 6-1. Deformation in the Grainger Formation at *Stop 3B*.



STOP 3C

FIGURE 6-2. Deformation in the Grainger Formation at *Stop 3C*.